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FOODS
AND PRINCIPLES OF
COOKERY

FOODS AND PRINCIPLES OF COOKERY

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PRENTICE-HALL, INC.

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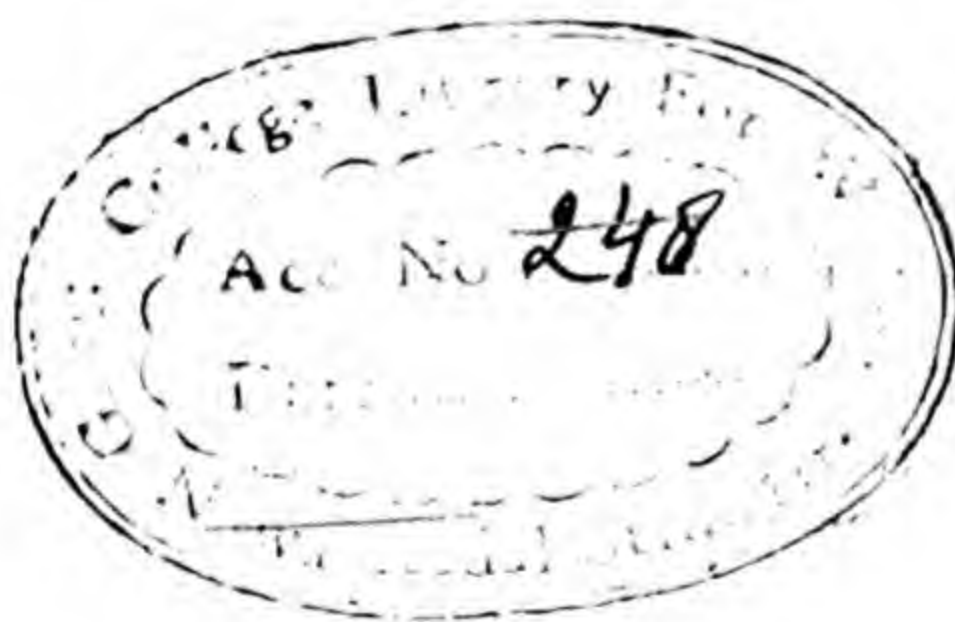
First Printing August 1948
Second Printing January 1949
Third Printing December 1951
Fourth Printing September 1953
Fifth Printing June 1955
Sixth Printing May 1958
Seventh Printing June, 1959

PRINTED IN THE UNITED STATES OF AMERICA

32324

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TO
MAY B. VAN ARSDALE



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PREFACE

This book is intended for student use as a text in a first course in foods on the college level. It is presumed that such a course will include the following: (1) Actual laboratory experience in food preparation, for which a manual including recipes—or the equivalent of such a manual—will be provided; (2) a comprehensive study of the foods with which the student will be dealing at the time and of the principles underlying all aspects of food preparation, such as, the selection of food; technics concerned with its handling and preparation, including any cookery involved; preservation of food; its storage, and so forth. It is for this second phase of such a course in foods and cookery that this text is intended.

For the most part, whenever physical, chemical or bacteriological phenomena contribute to underlying principles, their explanatory function is discussed in direct connection either with the foods or with the food preparations that are the subjects of study. Even so, it has seemed appropriate to include in this text chapters that are devoted entirely to these sciences in order to provide for any needed review of the fundamentals concerned, and to present pertinent information that may not have been included in previous science courses but which is necessary for a larger outlook upon certain physical and chemical phenomena as they apply to food problems. These chapters include studies in respect to: True and Colloidal Solutions, Acids and Bases, and brief general discussions of Carbohydrates, Fats, and Proteins. But it should be emphasized, as already implied, that these chapters should be used for review and reference on the part of the student, and not for studies in themselves, entirely divorced

from their applied intent. Specific references to their content permeate the various studies as to foods throughout the text.

It is assumed that a course in general chemistry either precedes (preferably) or is taken in parallel with this course in foods. This same assumption is made in regard to a course in the fundamentals of nutrition, since in many instances a discussion of cookery processes must include consideration of their effects upon the nutritional qualities of the food in question. Some background knowledge therefore in this subject, as well as in chemistry, will be of value to the student in using this text.

It is by no means necessary for the instructor to follow the sequence of study, chapter by chapter, as set forth in this text. While it is true that there are certain obvious chapter sequences—such as those dealing with Grains and Flours and those dealing with Preservation, Quick-Freezing, and Jelly—in the main the text will adapt itself to any sequence of food studies that may be the choice of the particular instructor.

The material that appears in fine print is either: (1) for the purpose of providing examples and illustrative material, or (2) for the presentation of pertinent discussions somewhat more advanced in character than should be expected or desired for some groups of students. The illustrative content should be helpful to all students; obviously, for many students the more advanced discussions should be entirely omitted.

The authors are grateful to Professor Helen Judy Bond for a thorough reading of the manuscript and constructive suggestions, also for her unceasing friendly interest in their endeavors. They take pleasure, too, in expressing their appreciation to Helen Spoor King for her valuable criticisms as she typed the manuscript.

The Authors

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FOODS
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COOKERY

CHAPTER I

TRUE SOLUTIONS—COLLOIDAL SOLUTIONS—SUSPENSIONS

Dispersed systems. Among the phenomena that are of vital importance in the living processes of both animals and plants are those pertaining to *true solutions*, *colloidal solutions*, and *suspensions*. But these phenomena are of importance, too, in cookery; hence in this connection they are of immediate concern.

In the language of chemists these two types of solutions and suspensions are frequently referred to as *dispersed systems* or just *dispersions*, meaning systems that are composed of two or more component substances dispersed in respect to one another. Dispersions vary from the simplest ones, which are composed of only two substances, such as sugar and water in true solution or gelatin and water in colloidal solution, to more complex bodies, exemplified by a cake batter which includes all three types of dispersions: a true solution of sugar, salt, and baking powder dispersed in water; a colloidal solution of proteins dispersed in water; and a suspension of the starch of flour, likewise dispersed in water.

SOME CONTRASTING CONDITIONS

The following paragraphs call attention to a few of the outstanding contrasts between the three types of dispersions. Further study of *true solutions* begins on page 5 and continues for the rest of the chapter. A further study of *colloidal solutions* appears in Appendix II, page 360.

True solutions. Properties. A true solution is (1) homogeneous, meaning that the liquid and dispersed substances are in even distribution, with the concentration of the dispersed substance the same in every part of the solution. Homogeneity as to a solution means, too, that (2) when it is examined by means of an ultramicroscope (p. 364) the dispersed particles cannot be distinguished from the dispersion medium. (3) Furthermore, although the dissolved substance (solute) and the dispersing liquid (solvent) have different densities, no matter how long a true solution may be permitted to stand—whether for hours or years—no separation of the more dense from the less dense substance occurs. Other properties of true solutions are: (4) both liquid and dispersed substances pass through filters; and (5) both diffuse through appropriate membranes (pp. 10, 14).

Size of dispersed particles and their character. These properties of *true solutions* lead to the obvious conclusion that distributed particles in such dispersions must be exceedingly small; and they are, indeed, believed to be single molecules or ions (p. 353) and less than 1 millimicron ($m\mu$)¹ in diameter.

Example: A familiar example of a true solution is a sugar-in-water dispersion. The sugar is in even distribution, hence in equal concentration in all parts of the solution. The dispersed sugar particles are not distinguishable even with the aid of the ultramicroscope. No matter how long the solution may stand, the more dense sugar never settles out, provided no evaporation of water occurs. Both the dispersed sugar and the water pass rapidly through filters, and both diffuse through membranes, such as the outer skins of fruits and seeds. The dispersed particles are believed to be single molecules of sugar; hence their ability to pass through pores of filters and membranes along with the water molecules.

Suspensions. Properties. Suspensions are in marked contrast to true solutions. They are obtained through the

¹ 1 micron (μ) = .001 millimeter

1 millimicron ($m\mu$) = .000001 millimeter

mechanical devices of mixing and stirring, as in the instance of a dispersion of raw starch and water. (1) The more dense substance begins to separate from the less dense substance as soon as the mixing and stirring cease. (2) The concentration of dispersed particles is not the same throughout the dispersion. (3) A suspension is heterogeneous, hence the dispersed particles are easily distinguished from the dispersion medium; frequently they are visible to the naked eye; always they are visible through an ordinary microscope. (4) The dispersed particles of a suspension do not pass through a filter. (5) They are not diffusible through membranes.

Size and character of dispersed particles. It is calculated that the diameters of dispersed particles of a suspension are more than 100 times the diameters of those within true solutions. Hence it is presumed that suspended particles are composed of aggregates of cohering molecules, thousands of them, and are therefore too large to penetrate filters or membranes.

Example: A dispersion of raw starch and water is an example of a suspension which, as has been said, is obtained by continued mixing. The more dense starch is continually attempting a separation from less dense water, consequently the concentration of starch is always greater in lower than in upper portions of the dispersion. A starch dispersion is heterogeneous, with dispersed starch particles easily distinguished not only through an ordinary microscope but by the naked eye. These massive starch particles are nonfiltrable; they do not diffuse through membranes; their diameters are more than one hundred times the diameter of dispersed particles of true solutions, hence they are believed to be made up of thousands of cohering starch molecules.

Colloidal solutions. *Size and constitution of dispersed particles.* Colloidal solutions lie within the range between true solutions and suspensions. The diameters of the dispersed particles can vary from greater than those in true solutions to less than the diameters of those in suspensions. Thus, it is presumed that colloiddally dispersed par-

ticles are composed of from hundreds of coherent molecules, as the dispersion approaches true solution in character, to thousands of coherent molecules as the solution approaches a suspension dispersion (Fig. 1).² It would follow, then, that the characteristics of colloidal solutions should range between those of true solutions and those of suspensions, and this is true to quite an extent.

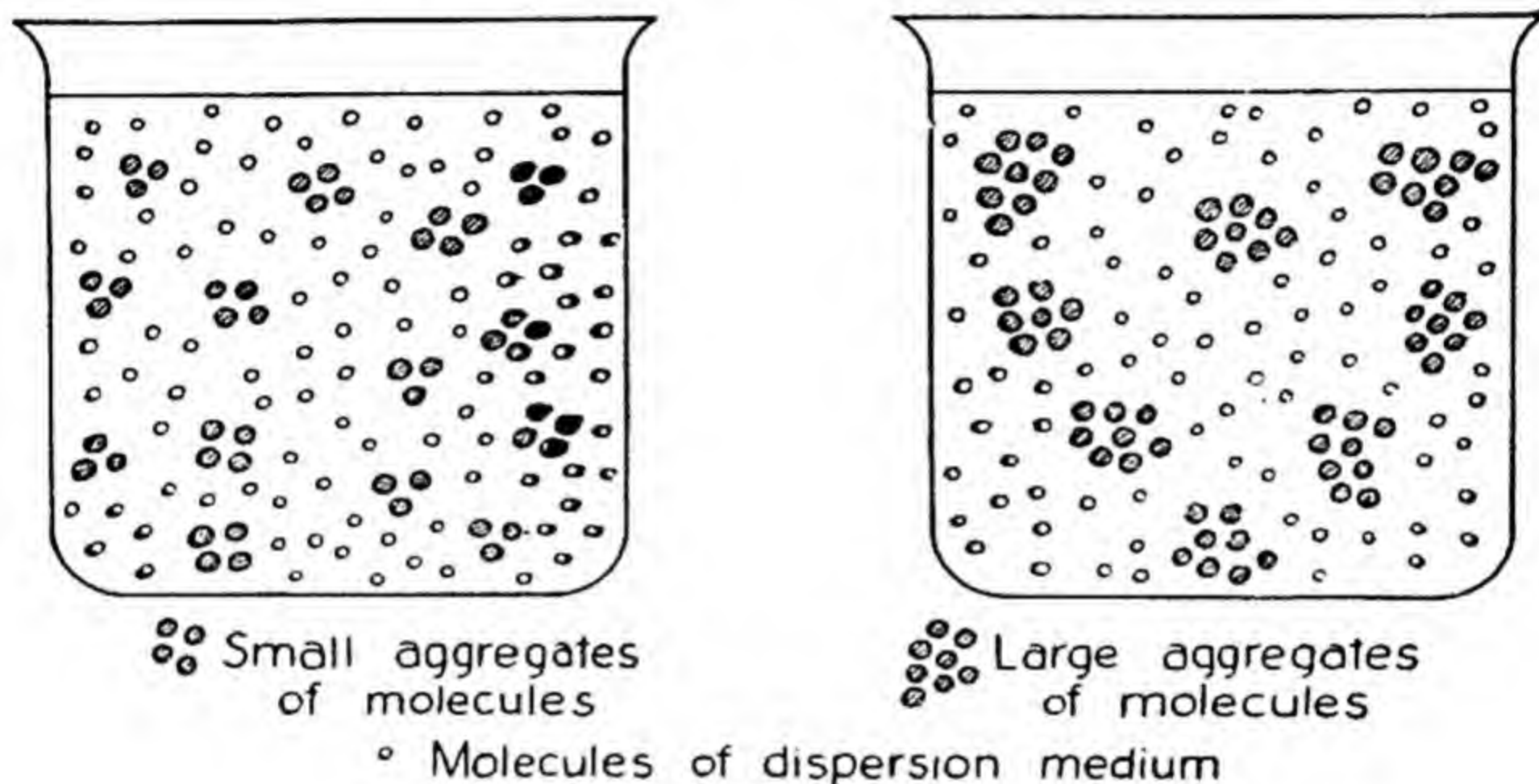


Fig. 1. Particles in colloidal dispersion.

Properties of colloidal solutions. (1) While some colloidal solutions appear to the eye to be homogeneous like true solutions, all are really heterogeneous. (2) The dispersed particles are not visible through an ordinary microscope, as is the case with suspensions, but when examined by means of an ultramicroscope (see note, page 364) their presence as discrete particles, distinct from the dispersion medium, can be detected. (3) There is always a tendency toward separation of dispersed substance from dispersion medium; with some colloidal solutions the separation may become apparent after a few minutes, with others after hours, or days, or even years. (4) As in the case of true

² It is a matter of controversy whether a colloidal particle is ever a single, very large molecule.

solutions, colloidal solutions are filtrable, but the ease with which they lend themselves to filtration varies from a fairly rapid to a very slow process. (5) While the dispersing liquid, such as water, of a colloidal solution is diffusible through membranes, colloiddally dispersed particles are diffusible either very slightly or not at all.

Example: An albumin-in-water dispersion is a colloidal solution in which the dispersed particles are presumed to be albumin molecule aggregates colloidal in size. By means of the ultramicroscope, light reflected at various angles from these albumin aggregates provides evidence that they are discrete particles in themselves as distinct from the water. Upon standing, the heavier albumin aggregates settle out, although slowly. Both the water and the albumin pass through a filter, but, again, the albumin very slowly. The water is diffusible through membranes, but not the albumin.

TRUE SOLUTIONS WITH WATER AS SOLVENT

An over-all study of true solutions is an enormous undertaking and entirely unnecessary for the present purpose, which calls only for such selections for discussion as will contribute to a better understanding of phenomena pertaining to cookery. With this purpose in mind, while it is true that solutions are possible which have liquids other than water as dispersion media,³ studies here will be confined almost exclusively to solutions which do have *water as the dissolving medium or solvent*, and which have for dissolved substances, or solutes, those that occur in foods, such as certain sugars, salts, and gases.

Character of solute. With water as solvent, the dissolved substance or solute can be *gaseous*, as is the case when oxygen is dissolved in water; or the solute can be a *liquid*, as in an alcohol-in-water solution; or it can be a *solid*, as in a sugar-in-water or a salt-in-water solution.

Solution defined. There are two definitions for a solu-

³ Alcohol, ether, and carbon tetrachloride are some liquids other than water that are used as solvents for various substances.

tion that are commonly given, related, of course, but from different viewpoints; and since it is well to be able to "see" solutions from the two viewpoints, both definitions are given.

1. The definition which incorporates outstanding properties already presented is as follows: *a solution (with liquid as solvent) is a homogeneous dispersion in which the solute is in even distribution throughout the dispersing liquid and shows no tendency whatsoever toward effecting a separation.* Hence, in examples of solutions just mentioned, the sugar is maintained in even distribution throughout the water as solvent, and the same is true of the carbon dioxide and of alcohol in their respective water solutions.

2. The second definition deals with the character of the dispersed particles and their distribution. Thus: *a solution is a dispersion in which the dispersed particles are single molecules (or ions (p. 353) or both).* According to this concept, dispersed particles in a sugar-in-water solution are single sugar molecules which, although moving about, maintain an even distribution in the solution and have no tendency to effect a separation. Likewise the dispersed particles in a solution of oxygen in water are single molecules of oxygen, maintained in even distribution with no tendency toward separation.⁴

Reason for permanence of dispersion. There are many more reasons than we shall attempt to give in this text as to why it is that in a true solution heavier and lighter-weight molecules remain continuously in even distribution. But two reasons are as follows: (1) Molecules of both water and solute are in constant vibration, but they mingle among each other with equal kinetic energies—the heavier molecules in slower vibratory motion, the lighter molecules in more rapid vibratory motion. (2) There is an inherent tendency for water molecules to get in between solute molecules. For further explanation of this phenomenon the student is referred to any comprehensive text on physics or chemistry.

⁴This statement refers to the oxygen which is in solution in the water, not to any insoluble portion of this gas which may be present and which collects in dispersed, plainly visible bubbles.

Properties of true solutions with water as solvent.

Some properties of *all* true solutions with liquids as solvents have been stressed previously (p. 2), therefore these apply to solutions with *water* as solvent. *Other* properties are discussed in the following sections.

Solutions in water are *transparent*, the reason being that since the distributed particles are either single molecules or ions, they are so ultramminute that light rays pass between them through the solution, unobstructed and unreflected.

The freezing and boiling points of a true solution.

The *freezing point of water alone*, meaning the temperature at which liquid water changes to solid water, is 0°C . (32°F .). The presence of a substance in solution in the water, however, depresses this freezing point with the result that *the solution freezes at a temperature below 0°C* . Certainly it is a well-known fact that temperatures below 0°C . are required for freezing sugar-in-water and salt-in-water solutions.

The *boiling point of water alone*, at standard pressure,⁵ is 100°C . (212°F .), but the presence of a nonvolatile substance in solution, such as any sugar or salt, increases the boiling point so that *the solution boils at a temperature above that at which water boils when alone, that is, above 100°C . (212°F .)*. Thus, a solution of sucrose in water, when boiling, is hotter than boiling water.

The extent of these effects. The extent both of the freezing point depression of a solution below 0°C . and of the boiling point elevation above 100°C . is directly proportional to the concentration of the particles present (molecules or ions or both), irrespective of what the substance may be.

Examples: 1. Given: Two solutions of sucrose, each of which contains $\frac{1}{2}$ pound of this sugar dissolved in 1 quart of water. Since the two half-pound quantities of this sugar include the same number of sucrose molecules, the molecule concentrations of the

⁵ Standard pressure is the pressure that is equal to that which is exerted by a column of mercury 760 millimeters high. It approximates the average annual pressure of the atmosphere at sea level.

two solutions are the same; hence their freezing points are depressed to the same extent below 0° C. and their boiling points are increased to the same extent above 100° C.

2. Given: Two solutions of sucrose, one containing 2 pounds of this sugar in 1 quart of water, the other containing 1 pound in 1 quart of water. Since the molecule concentration of the first solution is twice that of the second solution, the increase in the boiling point of the first solution above 100° C. and the decrease in its freezing point below 0° C. will be exactly twice these effects produced in the second solution.

Freezing and boiling points of electrolytes. Sugars belong to the class of compounds called *non-electrolytes*; salts, acids, and bases belong to the class called *electrolytes* (p. 356), among which is the salt sodium chloride, commonly called "salt."

In regard to the boiling and freezing points of water solutions of electrolytes, the facts are as follows: Given two solutions of *equal molecule concentrations*, one a solution of a non-electrolyte and the other a solution of an electrolyte, the increase in the boiling point of the *electrolyte solution* above that of water alone (above 212° F.) and the decrease in its freezing point below that of water alone (below 32° F.) will be *greater* than these effects in the solution of the non-electrolyte. The reason for this is that, when in water solution, a greater or less number of molecules of an electrolyte are dissociated, each molecule into two or more ions; therefore the *particle* concentration (remaining molecules and ions) in the solution of the electrolyte is greater than the particle concentration (molecules) in the solution of the non-electrolyte. And, as has been said, boiling and freezing point effects are in proportion to the concentration of dispersed *particles*, irrespective of whether the particles are molecules or ions or both.

Example: Given solutions of the same molecule concentration of sucrose and of sodium chloride, the sodium chloride solution will have a higher boiling point and lower freezing point than the sucrose solution. This is because in the sugar solution the dispersed particles are the sugar molecules, whereas in the sodium chloride solution some of the molecules have dissociated into ions—two ions from each molecule, a sodium ion and a chloride ion—hence the *particle* concentration in the sodium chloride solution is greater than that in the sugar solution.

Boiling and freezing points of solutions are of cookery concern. The fact that the sugar and salt solutions

which permeate foods freeze at lower temperatures than would be the case if water alone were the permeating liquid is of cookery significance, since this must be taken into consideration in the preparation of frozen desserts and in the preservation of foods by freezing (p. 315). Also the fact that sugar solutions boil at higher temperatures than water alone is of concern in the making of jellies and preserves as well as in the making of sirups, frostings, and candies.

True solutions exhibit osmotic pressure. It has been emphasized that in the formation of a true solution, such as a sucrose and water solution, the water and solute molecules through continuous motion establish an even distribution in respect to each other, and once established, unless some disturbance interferes, they maintain this condition as rapidly moving molecules of water and solute hit and rebound both from each other and the sides of the container. As a result of these impacts between myriads of molecules of water and solute, considerable pressure becomes established within and throughout the solution. *It is this inner-solution pressure that is called osmotic pressure.* Moreover, osmotic pressure is directly proportional to the concentration of dispersed particles within the solution. This is reasonable, because the greater the concentration of solute molecules (or molecules and ions), the greater will be the number of impacts of water and dispersed particles against each other and against any obstacle in their path, such as the sides of the container.

Examples: 1. Given: Two solutions of the sugar glucose, one solution containing $\frac{1}{4}$ pound of glucose in 1 quart of water, the other $\frac{1}{2}$ pound of this sugar in 1 quart of water. Since $\frac{1}{2}$ pound of glucose provides twice as many molecules as $\frac{1}{4}$ pound of this sugar, the second solution will be twice as concentrated in dispersed particles as the first solution; hence it will have double the osmotic pressure.

2. Given: Two solutions, one of glucose and one of sodium chloride, of equal molecule concentrations. Since most of the sodium chloride molecules are dissociated into ion particles—two ions for each sodium chloride molecule—the sodium chloride solu-

tion with its dispersed molecules and ions will have a greater osmotic pressure than the solution of glucose with its dispersed molecules.

Osmosis. Whenever two solutions, as of sugar and water, of different concentrations, hence of different osmotic pressures, are separated by a membrane which is permeable to both water and solute (Fig. 2), an attempt is made, by means of the passage of molecules of both water and solute through this membrane, to equalize the water-solute concentrations on both sides, and this is what happens: (1) *more solute molecules* will pass through the membrane from the solution of higher osmotic pressure, where more solute molecules hit against the membrane, to that of lower osmotic pressure (from *A* to *B*, Fig. 2) than vice versa; (2) contrariwise, *more water molecules* will pass from the solution of lower osmotic pressure, where the greater number of water molecules hit the membrane, to the solution of higher osmotic pressure (from *B* to *A*, Fig. 2) than vice versa. As a consequence, the more concentrated solution decreases in concentration as it increases in volume (Fig. 2 *C*) and the less concentrated solu-

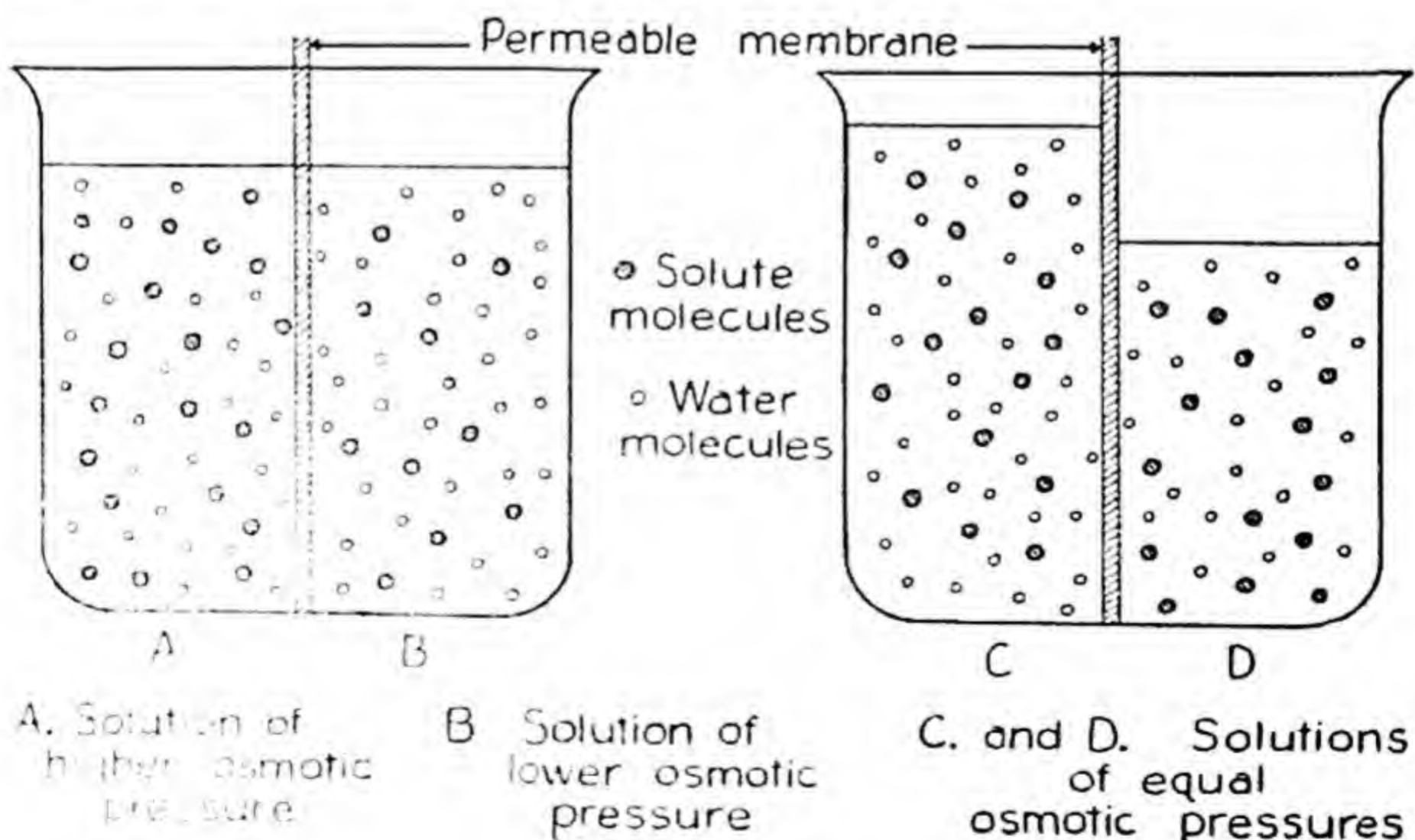


Fig. 2.

tion increases in concentration but decreases in volume (Fig. 2 D).

The attempt to equalize the concentrations of two solutions, separated by a permeable membrane, by diffusion of the water or solute (or both) through the membrane is the phenomenon called *osmosis*.

Examples: 1. When a plump, ripe fruit is put into a concentrated sugar solution, with the skin of the fruit as permeable membrane, more sugar will pass from the surrounding sugar solution, with its higher osmotic pressure, into the fruit with its lower sugar concentration, hence lower osmotic pressure, than will pass from the fruit to the outer solution. On the other hand, because of the greater concentration of water against the skin on the inside of the fruit than on the outside, more water passes from the fruit through the skin to the surrounding sugar solution than from the sugar solution into the fruit (Fig. 3). Consequently the fruit becomes sweeter and it shrivels.

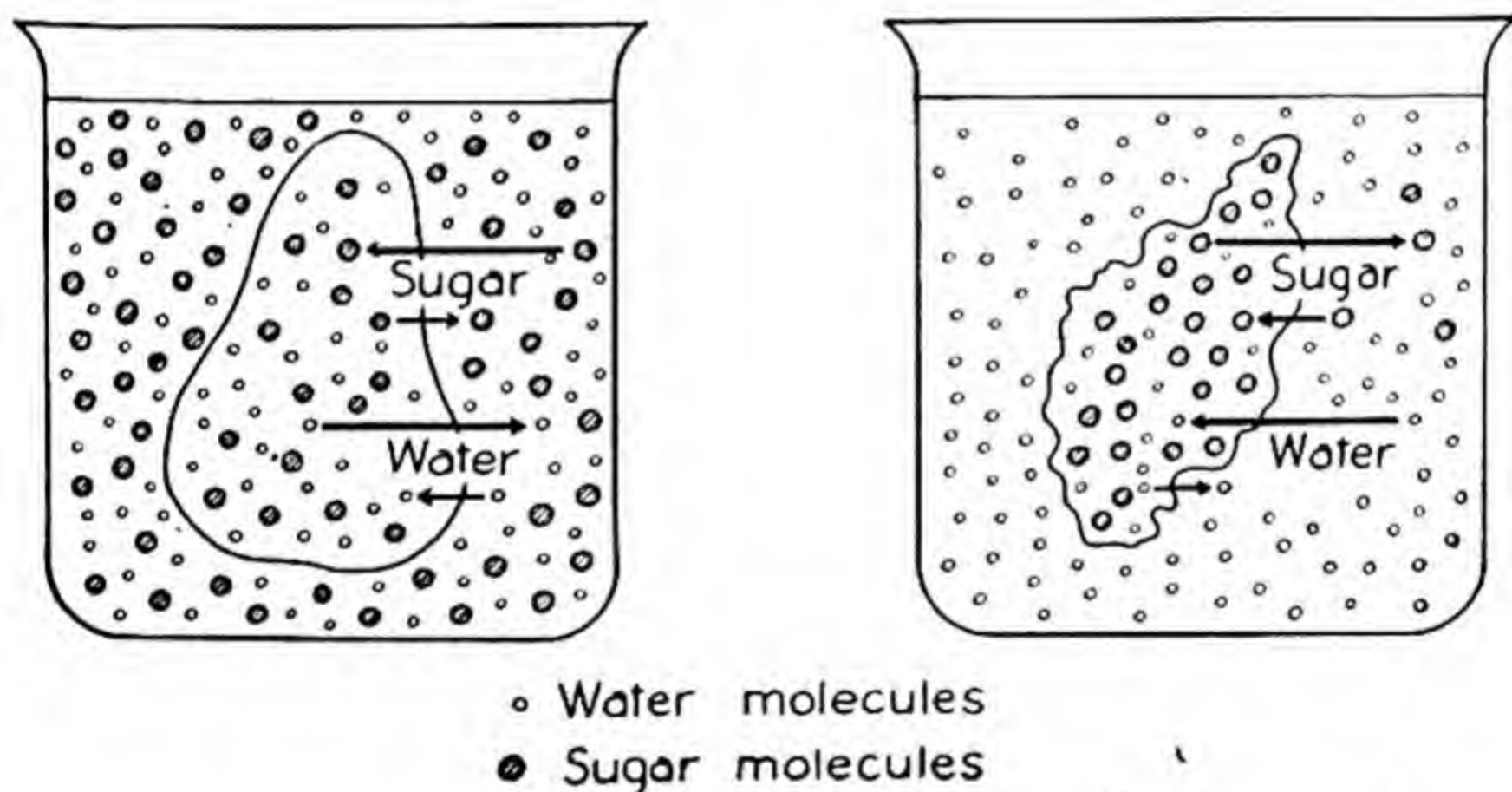


Fig. 3.

2. When a dried fruit or vegetable, such as dried prunes or dried Lima beans, is put into water, more sugar (or soluble salts or both) diffuses through the skin from inside the fruit or vegetable to the outside than vice versa, while more water diffuses from the outside into the dried fruit or vegetable than in the reverse

direction (Fig. 3). As a result, the surrounding water gains in sweetness (or saltiness or both) as the fruit or vegetable becomes more plump.

3. The content of any bacterium includes a true solution of salts and other substances in water, and it is enclosed by a membrane or wall which is permeable. Therefore when a bacterium is surrounded by a concentrated salt solution (brine), in nature's attempt to equalize solution concentrations inside and outside the cell, thereby aiming toward attaining solutions of equal osmotic pressure, more water molecules diffuse from inside the bacterial cell to the outer solution than in the reverse direction. As a consequence, the bacterium, becoming "dehydrated," is either inhibited in its activities or else killed. At the same time, obviously, more salt molecules diffuse into the bacterium than from the inside to the outer solution; but it is the "dehydration" that is emphasized here because of its significant destructive effect (p. 294).

SOLUTION CONCENTRATION UNSATURATED, SATURATED, AND SUPERSATURATED SOLUTIONS

Solution concentrations are of importance in cookery, especially as they apply to sugar solutions. Also, in cookery practice one frequently deals not only with sugar solutions which are either *unsaturated*, *saturated*, or *supersaturated*, but with the passing of one of these concentrations to another as a solution meets with changing conditions, including that of temperature. Furthermore, these differing solution concentrations and the changing of one to another are encountered in various parts of this text in connection with the discussions of specific cookery problems. It follows, then, that for those who are interested in cookery some comprehensive understanding of these relationships, in general, is desirable.

Dilute and concentrated solutions. In a *dilute* solution the quantity of solute in relationship to the quantity of water present as solvent is relatively small. But in a *concentrated* solution, the quantity of solute in relationship to that of water as solvent is relatively high.

Example: A solution which contains 2 grams of sucrose in 100 grams of water is undoubtedly dilute, while one which contains 150

grams of sucrose dissolved in 100 grams of water is, of course, a concentrated solution.

Both dilute and concentrated solutions are possible with *very* soluble substances, as in the case of sucrose cited in the foregoing example. But only dilute solutions are obtainable with *slightly* soluble substances. For example, under no conditions can any except very small quantities of oxygen be dissolved in water (see table, p. 15).

Solution concentration on a percentage basis. It is frequently important for one to use a solution of definite and known concentration. Many times, for this purpose, solutions are made up on a percentage basis,⁷ which, if accurate, calls for a definite weight of solute to definite weight of water (not weight of solute to volume of water). Thus, on this basis a 20 per cent solution, with ounce as weighing unit, would include 20 ounces of solute to 80 ounces of water; or, with grain as weighing unit, 20 grams of solute to 80 grams of water; while a 50 per cent solution would contain half solute and half water by weight.

Unsaturated and saturated solutions. *A solution is unsaturated if, when in contact with some of the undissolved solute, more of the solute will enter into solution. Hence, any sucrose solution is unsaturated (at the given temperature) if, when in contact with undissolved sucrose, it will dissolve more of this sugar.*

*A solution is saturated at a given temperature if, when in contact with some of the undissolved solute and without a change in temperature, it is unable to take more of this solute into solution.*⁸ Thus, if a sucrose solution of given temperature is in contact with some undissolved sucrose and no

⁷ While scientists frequently use solutions made up on a percentage basis, they also use solutions the concentrations of which are on either a *molar* or *molal* basis. Any college textbook for beginning chemistry will give the basis for these solution concentrations.

⁸ Experimental evidence indicates that, actually, when a saturated solution is in contact with undissolved solute, some of the latter does enter the solution, but that an exactly equal quantity of solute leaves the solution to join the portion still undissolved. In other words, the portions of solute entering and leaving the solution are at equilibrium.

SUMMARY

PROPERTIES OF TRUE SOLUTIONS, COLLOIDAL SOLUTIONS, AND SUSPENSIONS

True Solutions	Colloidal Solutions ^a	Suspensions
Dispersed particles, less than one millimicron (m μ) in diameter (p. 2). Believed to be single molecules or ions.	Dispersed particles greater in diameter than those of true solutions and less than those of suspensions. Believed to be aggregates of from hundreds to thousands of molecules.	Dispersed particles are massive and are very large molecule aggregates.
Transparent.	Either clear or translucent to the naked eye and under an ordinary microscope. From slightly to decidedly translucent when examined by the ultramicroscope.	Turbid.
Light rays pass through.	Light rays scattered by dispersed particles. ^a	Opaque to light.
No tendency of separation of solute from solvent.	Tendency toward separation of micelles (p. 363) from dispersion medium. May be considerably delayed.	Separation of dispersed substance is almost immediate.
Exhibit osmotic pressure.	Exhibit either no osmotic pressure or very slight. ^a	No osmotic pressure effect.
Both water and dispersed substance pass through filter and diffuse through suitable membranes.	Dispersed particles pass through ordinary filtering media. Dispersed substance either nondiffusible or difficultly so. ^a	Dispersed substances nonfiltrable and nondiffusible.
Boiling point of solution of non-volatile substance higher than that of water alone.	Boiling point either same as that of water alone or elevated very slightly. ^a	Boiling point same as that of water alone.
Freezing point below that of water alone.	Freezing point either same as that of water alone or very slightly depressed. ^a	Freezing point same as that of water alone.

^a See Appendix II, page 360.

more of the sugar becomes dissolved, it follows that the solution is saturated—at this temperature. Specific examples will be given presently.

Saturated solutions of solid substances and the temperature factor. The solubility of most solid substances increases with increasing temperatures of the solutions concerned, which means that for most solids the higher the temperature of the solution, the greater its concentration must be at the saturation point.

Example (also see accompanying table): In regard to solutions of sodium chloride. For saturation at 20° C., 1 liter of water must contain 360 grams of sodium chloride. For saturation at 100° C., 398 grams must be dissolved in 1 liter of water.

In regard to solutions of sucrose. For a saturated solution of sucrose at 20° C., 2039 grams must be in solution in 1 liter of water. If the solution is at 100° C., 4872 grams in 1 liter of water is required for saturation.

For saturation in 1 liter of water at given temperatures

<i>Substances which are solids</i>	at 0° C.	at 20° C.	at 60° C.	at 100° C.
Sodium bicarbonate	69.0 gm.	96.0 gm.	164.0 gm.	
Sodium chloride	357.0	360.0	373.0	398.0 gm.
Sucrose (cane sugar)	1792.0	2039.0	2873.0	4872.0
<i>Substances which are gases</i>				
Oxygen	0.06945 gm.	0.04339 gm.	0.02274 gm.	
Carbon dioxide	3.34600	1.68800	0.57600	

Questions and answers on saturated solutions. The following questions are in specific reference to saturated solutions of sucrose because of the important bearing that this sugar, in differing solution concentrations, has in cookery problems; but the same principles will apply to solutions of

all solid substances which are increasingly soluble with increasing solution temperatures. So, given a *saturated solution* of sucrose at any temperature:

1. What happens when the temperature of the saturated solution is raised?

Answer. The sugar solution will be unsaturated at all higher temperatures, provided no more sucrose is introduced.

2. What happens when the temperature of the saturated solution is lowered?

Answer. (a) One possibility, and the one less likely to happen, is as follows: as the solution cools, all sucrose that is in excess of the quantity required for saturation at each lower solution temperature attained may precipitate, obviously leaving behind a succession of saturated solutions, each with a less quantity of dissolved sugar.

(b) The second and *more probable* happening, especially if the saturated sugar solution is not disturbed, is as follows: as the solution cools, it will continue to hold in solution the excess sucrose above the quantity required for saturation at each lower temperature, and as a consequence the solution becomes supersaturated.

Supersaturated solution. As implied in the example just given, *a supersaturated solution retains in solution an excess of the solute over and above that which is necessary to produce saturation at the given temperature.*

Questions and answers on supersaturated solutions. As previously, these questions will be asked and answered in terms of supersaturated solutions of sucrose, but, also as said previously, the same principles will apply to supersaturated solutions of other substances.

1. How can a supersaturated solution of sucrose be obtained?

Answer. It can be made by saturating the solution with sucrose at a higher temperature, then lowering the temperature gradually; at all lower temperatures, as long as no precipitation of sucrose occurs, the solution will be supersaturated.

2. What happens if a crystal of sucrose is dropped into a supersaturated solution of this substance?

Answer. The added crystal acts as a "seed" around which sucrose, precipitating from solution, will gather. This precipitation will continue until the excess sucrose above saturation at each lower temperature attained has dropped out of solution.

3. What happens if a supersaturated solution of sucrose is disturbed, as by stirring?

Answer. Sucrose will begin to precipitate from solution. This precipitation will then continue until the excess sucrose above saturation at each lower temperature attained has dropped out of solution.

Solubility of gaseous substances. The solubility of all gaseous substances decreases with increasing temperatures of the solution. Accordingly, cold water dissolves more air (a mixture of oxygen, carbon dioxide, and nitrogen) than warm water; hence when cold water which is holding air in solution is warmed, the quantities of these gases in excess of amounts required for saturation at the higher temperatures will bubble out. Of cookery interest is the fact that the solution which permeates a batter or dough of a flour mixture⁹ is able to hold more gases in solution when it is cold than when it becomes warmer in the heat of the oven.

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FRANCIS, C. A., and MORSE, E. C., *Fundamentals of Chemistry and Applications*, 2nd ed. New York: The Macmillan Company, 1943.
SWEETMAN, M. D., *Food Selection and Preparation*, 3rd ed. New York: John Wiley & Sons, Inc., 1943.

⁹ This refers only to the gases held in solution, not to gas bubbles that are entrapped in the dough mesh and are therefore in suspension.

CHAPTER II

CARBOHYDRATES

Carbohydrates are the first of the foodstuffs to be made in plants from inorganic materials taken from the soil and the air; then plants use them, in unknown ways, for the making of other foodstuffs including fats and proteins. They contribute to the skeletal structure of all plants, and plants use them as foods in their embryonic development and growth. Certain carbohydrates are essential foodstuffs for man and other animals; and man has learned how to use various carbohydrates in his external affairs: for fuels, for construction, and for making almost countless materials that have come to be of enormous consequence.

Origin of term. The word "carbohydrate" means "hydrate of carbon," an implication which is incorrect since carbohydrates are not hydrated carbon, that is, they are not composed of carbon in combination with water. It is true, however, that most, but not all, carbohydrates do contain the elements hydrogen and oxygen in the proportion in respect to each other in which they are present in water: that is, (1) molecular weights of most carbohydrates are known to contain two atomic weights of hydrogen to every one atomic weight of oxygen; accordingly, (2) it is believed that molecules of these carbohydrates contain two atoms of hydrogen to every one atom of oxygen; ¹ a relationship that is indicated in the following formulas for two representative members of this class of compounds:

¹ See Appendix III, page 374.

Glucose.....	with formula.....	$C_6H_{12}O_6$
Sucrose.....	with formula.....	$C_{12}H_{22}O_{11}$

Occurrence. *Celluloses* and *starches* are outstanding among *insoluble carbohydrates*. Celluloses comprise the skeletal framework of plants: trunks, branches, twigs, stems, and considerable portions of leaves; cotton is almost pure cellulose. Starches are storage carbohydrates, held as reserve food; they are stored in various locations depending upon the particular plants: in seeds as with wheat and corn, in tubers as with potatoes, and in roots as in the carrot and beet.

Sugars are circulating carbohydrates in the sap of plants and blood of animals, and, obviously, only *soluble carbohydrates* can function in this way. Sugars, as is well known, are also components of some ripe fruits, such as peaches, and some unripe fruits, commonly regarded as vegetables, such as green peas and sweet corn.

Classification. All water-soluble carbohydrates are sugars; some are *monosaccharides*, frequently called *simple sugars*, and others are *disaccharides*. Insoluble carbohydrates are celluloses, starches, and starch-like compounds called dextrins, all of which come under the classification of *polysaccharides*.

Monosaccharides

and

Disaccharides



Soluble carbohydrates
called **Sugars**

Polysaccharides



Insoluble carbohydrates
called **Celluloses**
Starches
Dextrins

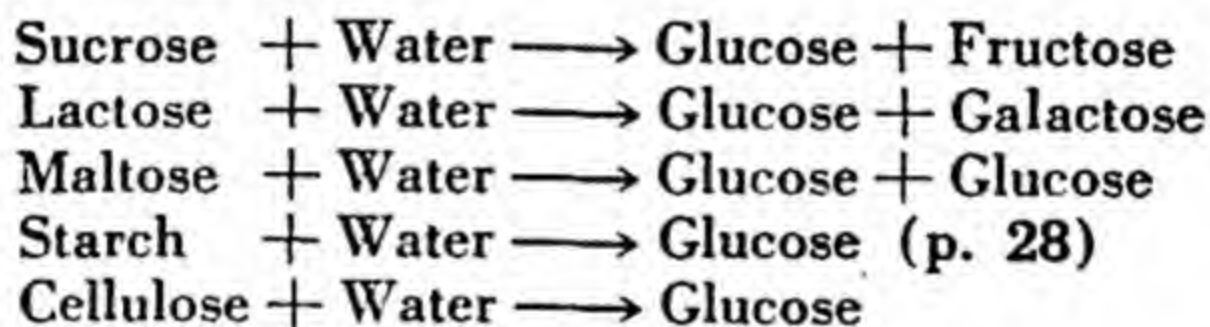
The term *monosaccharides* applies to carbohydrates that do not react with water in hydrolysis to make simpler compounds, hence their specification as simple sugars. A *disaccharide* is composed of two monosaccharide radicals. A *polysaccharide* is composed of many monosaccharide radicals

in combination with one another. Both disaccharides and polysaccharides react with water in hydrolysis to make simple sugars as end products.

MONOSACCHARIDES

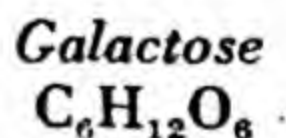
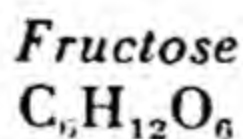
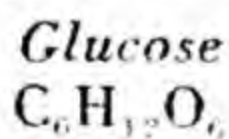
Glucose, fructose, and galactose. Chief among monosaccharides are the simple sugars *glucose*, frequently called *dextrose*, and *fructose*, sometimes called *levulose*. Both are present in various fruit juices, where they are commonly associated with sucrose. Another simple sugar of importance is the monosaccharide *galactose*.

How made from other carbohydrates. Glucose and fructose are products of the hydrolysis of sucrose; glucose and galactose are made by the hydrolysis of lactose; and glucose is the final product of the hydrolysis of maltose, starches, and celluloses.



Specific conditions for the procedure of these reactions are considered under the studies of disaccharides and polysaccharides.

Composition. Glucose, fructose, and galactose have exactly the same composition as is indicated in their identical empirical formulas:



For the two uses of these formulas, to represent: (1) composition of molecular weights and (2) composition of molecules of these substances; also for explanation of why it is possible to have several sugars with the same composition, the student is referred to Appendix III, page 374.

Properties of simple sugars. The important fact that *glucose*, *fructose*, and *galactose*, like all sugars, are **soluble**

in water has already been stressed. Like all sugars, too, these monosaccharides are *sweet*. As indicated in the accompanying table, glucose is less sweet than either fructose or sucrose, while lactose is the least sweet of sugars. Fructose is the sweetest of all sugars.

Order of sugars as to sweetness from most to least²

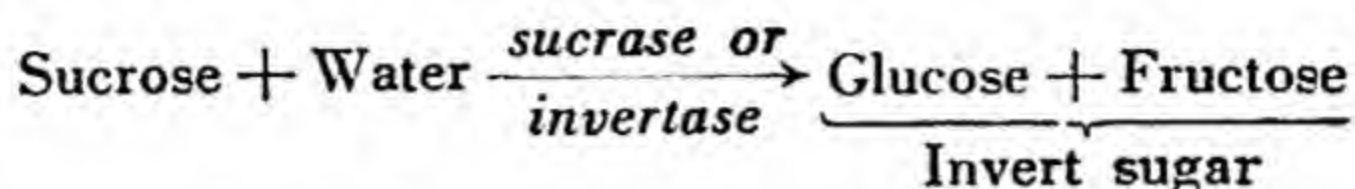
Fructose	173.3
Sucrose	100.0
Glucose	74.3
Maltose	32.5
Galactose	32.1
Lactose	16.0

Many food preparations and confections contain sucrose as the only sugar present, while others may contain not only sucrose but fructose and glucose—the two sugars that comprise invert sugar. Therefore, the sweetness of any food or confection must depend upon the particular sugar or sugars present and their concentrations; also, if more than one sugar is involved, upon their proportions. These simple sugars, in common with all sugars, usually *form crystals* when precipitating from solution in water. Monosaccharide sugars are *subject to two types of fermentation*: (1) the type which yields carbon dioxide and alcohol, and (2) the fermentation which yields acids, chiefly lactic acid, and various gaseous substances as products. It is the carbon dioxide and alcohol type of fermentation with which this text is chiefly concerned, since it is through these reactions that carbon dioxide is made for aeration of yeast breads (p. 99). The second type of fermentation reaction is involved in the making of certain fermented milks (p. 152).

Invert sugar. Invert sugar is a mixture of glucose and fructose that is produced by the hydrolysis of sucrose. From

² Biester, A., Wood, M. W., and Wahlin, C. S., "Carbohydrate studies. 1. The relative sweetness of pure sugars," *American Journal of Physiology*, Vol. 73 (1925), pp. 387-396

a foods angle this reaction takes place through the agency of the enzyme sucrase that is present in bakers' yeast (p. 25);



from a physiological angle the reaction occurs in the alimentary tract due to the presence of this enzyme in intestinal juices. But this mixture of glucose and fructose can also be made from sucrose without catalytic aid, although more slowly, at the relatively high temperatures that are maintained by boiling of a solution of sucrose in water; under these circumstances, should the presence of a catalyst be desired in order to speed up the reaction. hydrogen ions (p. 40) can be introduced.

When invert sugar is produced by the hydrolysis of sucrose, the glucose and fructose are present in exactly equal quantities in the resulting mixture. And it is an interesting fact, also of importance from the angle of some food preparations, that glucose and fructose, as present in invert sugar mixture, have less tendency to precipitate from solution than when each is the only sugar occurring in the solution.

For a discussion of significance of the terms *dextrose* as applied to glucose, of *levulose* as applied to fructose, and of *invert sugar* for a mixture of these two monosaccharides, the student is referred to Appendix III, page 374.

Galactose. This simple sugar has no importance in cookery. Seemingly its sole occurrence in nature is as one of the products of the digestion of lactose in the intestine. Even after absorption into the blood it appears to have been converted into glucose. In mammals it may possibly be made in the mammary gland, during the period of lactation, in order to contribute to the synthesis of lactose (pp. 23, 151).

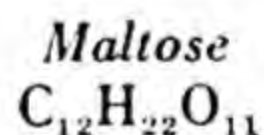
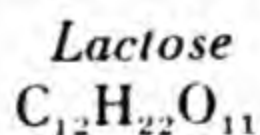
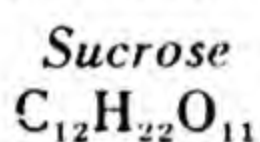
DISACCHARIDES

The three disaccharides of chief importance are sucrose, maltose, and lactose, with sucrose of most importance in food preparations.

Occurrence in nature. *Sucrose* is present in the sap of plants and in fruit juices; the sap of the sugar cane and sugar maple, also the juice of the sugar beet, are especially rich in this disaccharide. *Maltose* is an intermediate product in the digestion of starch (p. 28), consequently it is present: (1) in any starch mass that is undergoing either salivary or intestinal digestion; (2) in malted grains that are undergoing digestion through the agency of diastase (p. 100) in the process of making alcohol; (3) in germinating grains, also through the agency of diastase, as the embryo develops into a seedling plant. Other than these instances maltose is not a naturally occurring carbohydrate. *Lactose* occurs in nature only in the milk of mammals.

Why disaccharides. These sugars are called disaccharides because upon reaction with water in hydrolysis two monosaccharides are made. As pointed out previously (p. 20), with sucrose the monosaccharide products are glucose and fructose; with lactose they are glucose and galactose; and with maltose they are both glucose.

Same empirical composition. As is true of the monosaccharides just discussed, the three disaccharides—sucrose, lactose, and maltose—have identical composition as represented in their identical empirical formulas:



An interpretation of these formulas—as they apply *first* to the composition of molecular weights of sucrose, lactose, and maltose and *second* to the composition of their molecules—is similar to the interpretation of the formulas for the monosaccharides as given in Appendix III, page 374.

The fact that *three different disaccharides are possible with the same composition* is accounted for in the belief that some atoms are placed differently in space in respect to each other within the three molecules. Structural formulas which represent atom placements within molecules of these disaccharides can be found in any comprehensive text on organic chemistry.

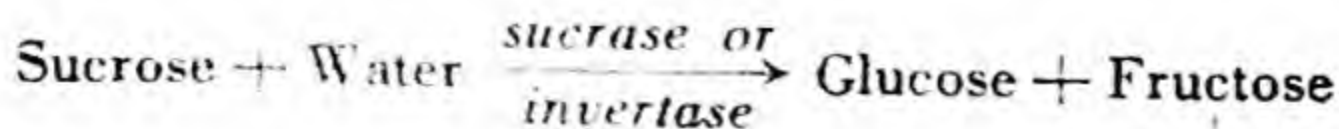
Properties of disaccharides. Soluble and sweet. The fact that sucrose, maltose, and lactose *form true solutions*

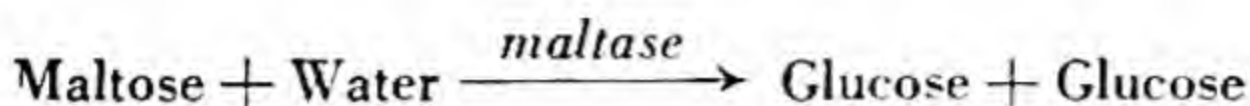
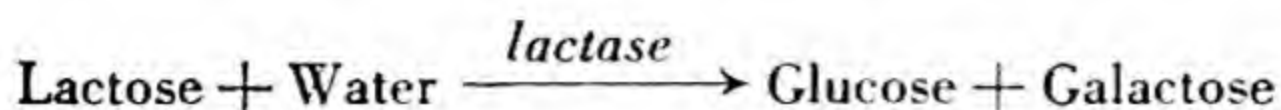
with water is of great importance: the transportation of sucrose to all cells throughout plants is thus assured; also, owing to their being in solution, all three of the disaccharides are rendered more available for speedy digestive reactions in the alimentary tract. The water-solubility of disaccharides, especially that of sucrose, is important, too, in the preparation of foods. *The relative sweetness* of these sugars has already been presented (p. 21).

Form crystals. When precipitating from solution these sugars usually form crystals, large or small, depending upon prevailing conditions. A more detailed discussion of this important property, as exemplified by sucrose, is given in another section of this text (p. 35), at which time conditions will be stressed that determine precipitation from solution, crystallization, and crystal size of sugars.

Subject to hydrolysis. All disaccharides react with water in hydrolysis to make simple sugars. Any one of these reactions can be accomplished by boiling with water, as in the making of boiled frostings from sucrose. But the hydrolysis of any disaccharide is more speedy if hydrogen ions in sufficient concentration are present; this condition can be obtained by a low concentration of a strong acid, such as hydrochloric acid, or a higher concentration of a weak acid, such as tartaric acid, or of an acid salt, such as potassium acid tartrate (cream of tartar). Needless to say, the latter sources of hydrogen ions for speedy disaccharide hydrolysis are the only sources that are advisable in food preparations. The hydrogen ions are claimed to function as a catalyst.

But the hydrolysis of all disaccharides takes place even more rapidly, and at ordinary temperatures, in the presence of appropriate enzyme catalysts—sucrase (invertase) for hydrolysis of sucrose, lactase for hydrolysis of lactose, and maltase for hydrolysis of maltose.





Sucrase and maltase are present in bakers' yeasts, which is of significance in the making of yeast breads (see following section, also p. 100); both are also present in yeasts that are used for making beverages such as beer and ale. All three of these enzymes are present in the digesting mass in the intestine.

Fermentation. When bakers' yeast is introduced into a mixture which contains either sucrose or maltose, a fermentation reaction begins presently to take place during which carbon dioxide and alcohol are made. A delay in fermentation occurs because actually, a series of reactions is involved: *first*, the hydrolysis of the disaccharide (or disaccharides) to make the monosaccharides concerned, the reaction being speeded by the appropriate yeast enzyme, as specified in the foregoing equations; *second*, the conversion of the monosaccharides to carbon dioxide and alcohol, the reactions being catalyzed by the yeast enzyme zymase (p. 100).

Fermentation of lactose with bakers' yeast does not take place because this yeast does not contain a lactase for the essential preliminary hydrolysis of lactose to monosaccharides (p. 23).

POLYSACCHARIDES

Occurrence. Polysaccharides of natural occurrence are cellulose and starches, which are present in plants, and glycogen, which occurs in animals. It has already been said that *celluloses* form the structural framework of all parts of plants, while *starches* are storage foods (stored in terminal parts of plants for contributing to their continued growth, and stored in seeds to provide food for germination of em-

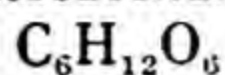
bryos and growth of new plants). *Glycogen* is present in the cells of the liver and muscles of animals: in the liver it is a storage carbohydrate, in muscles it plays an important part in reactions during which energy is made for body needs. *Dextrins* are also polysaccharides but, like the disaccharide maltose, they do not occur in nature save as intermediate products of the hydrolysis of starches (p. 28) toward production of glucose as an end product.

Polysaccharides and cookery. *Celluloses* do not serve as foodstuffs for humans but they are of some importance physiologically, since by providing "bulk" in the intestinal tract, their presence has a favorable effect on peristaltic movements. A softening of cellulose fibers, such as those of celery and cabbage, during cooking procedures is, at times, of importance. *Dextrins* are of little concern in cookery. Aside from the very small amounts of dextrins that may be present on brown surfaces of toast and baked breads, and the small quantities that are mixed with glucose in corn sirups (p. 30), they occur only occasionally in food products. As for *glycogen*, it disappears rapidly from liver and muscle tissues (p. 197) after the death of the animal, therefore it is not one of the foodstuffs to be reckoned with in meat cookery. *Starches* are the polysaccharides of prime food importance, hence the polysaccharides of chief interest in food preparations (p. 43).

Pectin. This polysaccharide has not been mentioned previously in this chapter. It is of importance only in the making of preserves such as jellies, jams, and marmalades (p. 331). The monosaccharide product of its hydrolysis is galactose. Further discussion of this polysaccharide appears in the chapter on jellies (p. 332).

Composition and why polysaccharides. Celluloses and starches, like all polysaccharides, are composed of many combined monosaccharide radicals, each of which is deficient in hydrogen and oxygen in the same proportion in which these elements are present in water. This is indicated in the following formulas:

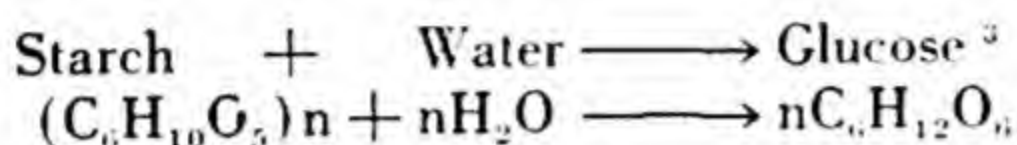
*Formula for complete
monosaccharide*



*Formula for polysaccharide*³
 $(\text{C}_6\text{H}_{10}\text{O}_5)_n$

n represents the unknown number of monosaccharide radical constituents.

It follows from the foregoing that when the hydrolytic reaction between water and a polysaccharide is *complete*, the end product is the monosaccharide involved, usually glucose. Thus:



In the polysaccharides with which this chapter is chiefly concerned—celluloses, starches, glycogen—the combined monosaccharide radicals are all glucose. Pectin, however, contains combined galactose radicals, while a polysaccharide component that is peculiar to the dahlia tuber and the Jerusalem artichoke, called inulin, is composed of combined fructose radicals.

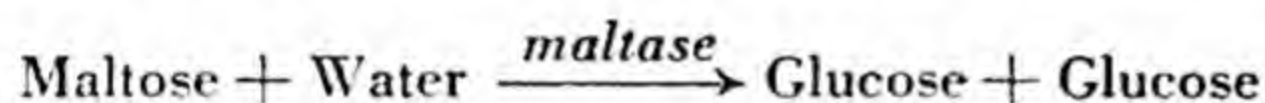
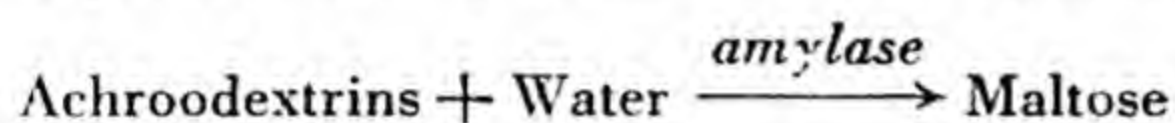
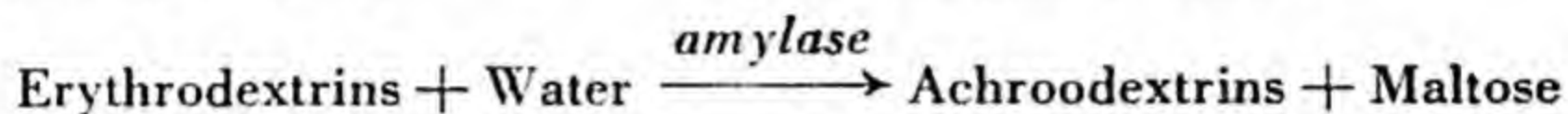
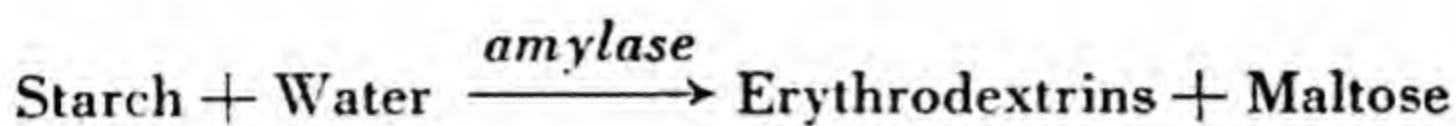
Properties of polysaccharides. Solubility. All polysaccharides are incapable of forming true solution with water. *Celluloses form suspensions*, hence they separate readily from a water dispersion (p. 3). In cold water, *starches form suspensions* from which they also precipitate readily. The dispersion behavior of starches in boiling water, to give either colloidal (p. 14) or suspension dispersions, is of such cookery significance that the subject is discussed in the separate chapter that deals entirely with starches (p. 43). *Glycogen* enters spontaneously⁴ into *colloidal dispersion* with water.

Tendency toward hydrolysis. For the *hydrolysis of celluloses*, boiling for hours in strongly acid solution is necessary, as in a solution which contains a little sulfuric acid or hydrochloric acid. The end product of cellulose hydrolysis is glucose.

³ See Appendix III, page 374.

⁴ This means that no outside mechanical assistance, such as mixing or stirring, is necessary for accomplishing a water-glycogen colloidal dispersion.

Starch hydrolysis takes place fairly rapidly in a dilute solution of a strong acid, but very slowly in solutions of organic acids (pp. 345, 356). As a consequence, little hydrolysis of starch occurs in cookery procedures that involve this foodstuff. But hydrolysis of starch proceeds rapidly in the presence of specific enzymes; and there is evidence that the reactions take place in stages with various dextrans and maltose appearing as intermediate products toward the making of glucose as end product. The following word equations are representative of these reactions:



The source of these enzymes for the promotion of reactions that are essential to the leavening process in the making of yeast breads is discussed under the subject of bread-making (p. 100). For digestive reactions on the part of humans, an amylase, called ptyalin and provided in the saliva, catalyzes the hydrolysis of a portion of the starch of the food mass through the dextrans to the maltose stage, before the ptyalin is destroyed by the too-high hydrogen ion concentration eventually encountered in the stomach. In the intestine an amylase, called amylopsin, and maltase are both provided so that starch digestion can be carried completely to the glucose end product in this region.

Polysaccharides and fermentation. When one remembers that it is the monosaccharides that are chiefly subject to fermentation (p. 21), it follows that celluloses and starches in themselves do not ferment to make carbon dioxide. But if conditions are obtained which favor the hydrolysis of the

polysaccharides to glucose, and if zymase is present, then fermentation does occur.

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CHAPTER III

SIRUPS, SUGARS, SUGAR CRYSTALLIZATION

Corn sirup and corn sugar. Although the hydrolysis of starch is not frequently encountered in cookery processes, the reactions concerned are of commercial significance in the manufacture of corn sirup and corn sugar. In processing starch for the purpose of obtaining these products, the reactions are catalyzed either by hydrogen ions alone, supplied by a strong acid such as hydrochloric acid, or by consecutive use of hydrogen ions and appropriate enzymes.

Corn sirup, as the name implies, is made from corn starch by permitting the starch hydrolysis to continue only until a partial conversion of the starch yields, as products, a mixture of the various hydrolytic derivatives, namely, dextrans, maltose, and glucose, all dispersed in water. When the reactions have been carried as far as is desired, the hydrogen ions are neutralized and the enzymes destroyed, then the dispersion is clarified, decolorized, and concentrated by evaporation of water. The product obtained is a clear, almost colorless, viscous, liquid dispersion which contains approximately 75 per cent solids and 25 per cent water. This sirup has a bland, slightly sweet flavor.

Dark corn sirup is colorless corn sirup to which small amounts of *raw-cane* sirup (p. 31) and molasses have been added. Therefore, the product is darker in color and more distinctive in flavor than is the light corn sirup described above.

Uses. Both light and dark corn sirups are used in the home as table sirups, also in the preparation of candies and frostings. They find a more extensive use, however, in commercial food industries, in which they function as important ingredients in canning and in the making of baked products and confections.

Corn sugar is also made from corn starch, but by allowing the hydrolysis of starch to carry forward to completion so that glucose is the final product in the solution concerned.

After neutralization of the acid used for catalyzing the reactions and removal of other substances present as impurities, water is evaporated and glucose is precipitated in crystalline form. This product is sold under trade names such as cerelese and dyno.

As is true of glucose from any source, corn sugar is only approximately three-quarters as sweet as sucrose (p. 21) and it is also less soluble than sucrose, therefore its use in cookery is limited. Like corn sirup, corn sugar is used in the canning, baking, and confectionery industries.

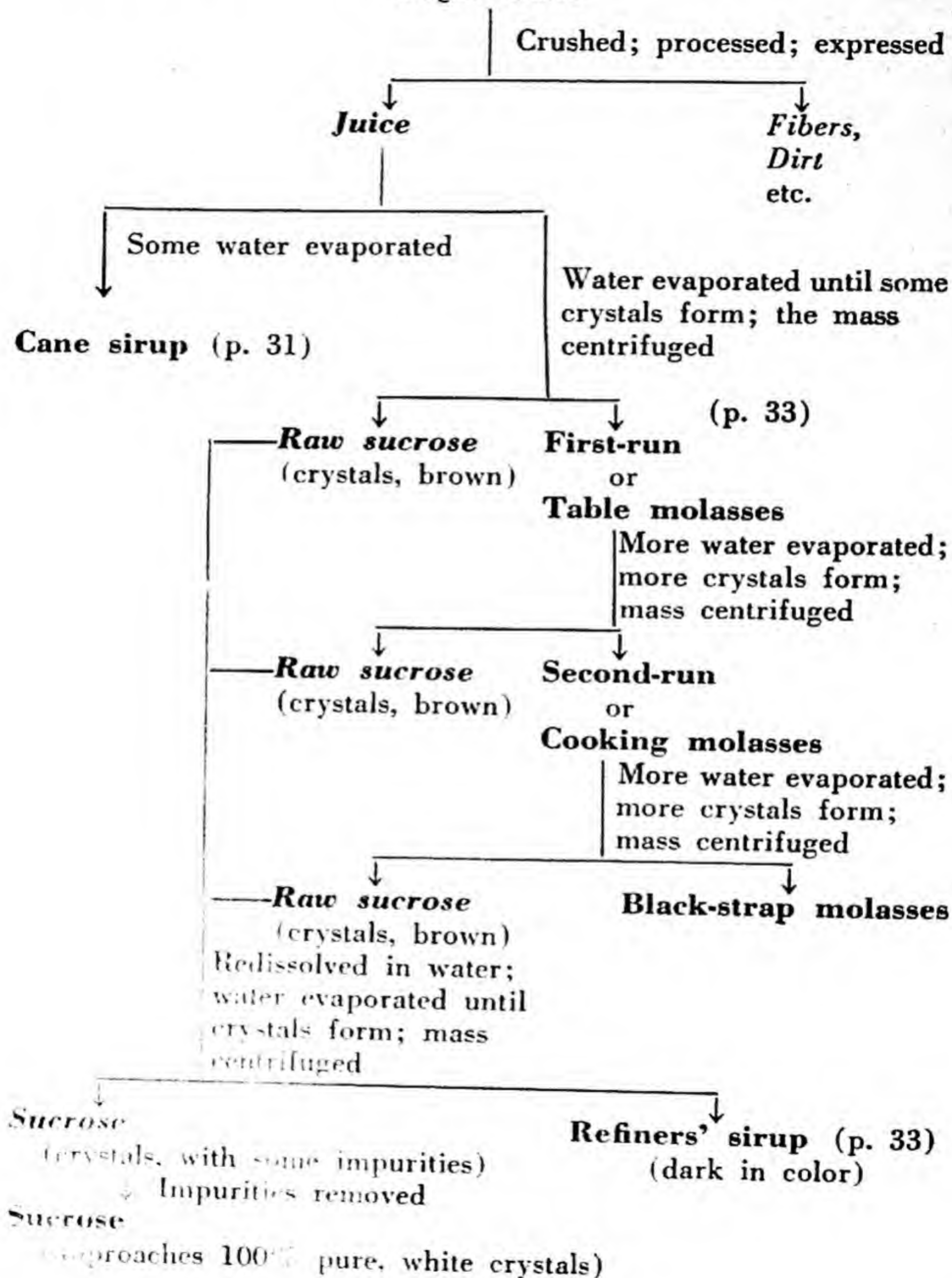
Cane sirup is the juice that is expressed from the crushed sugar cane with dirt, cane fibers, and other impurities removed. Water is evaporated by boiling until concentration of the sirup is of desired density. This sirup contains all of the sucrose that was originally present in the sugar cane (p. 32).

Molasses is the dark, viscous sirup that remains as fractions of sucrose are precipitated from the processed juice of either sugar cane or sugar beets. The sucrose at this stage contains many and various impurities, hence it is referred to as "unrefined" or "raw" sugar.

Molasses from the sugar cane.¹ During the processing of sugar cane, several successive fractions of unrefined sucrose are separated by crystallization, and with each sucrose fraction thus precipitated from the dispersion a different

¹ The molasses obtained along with "raw" sugar made from beets has no cookery uses but, instead, is used as feed for cattle.

SUMMARY, SUGGESTIVE OF PROCESSING OF SUGAR CANE
Sugar Cane



grade of molasses results. The procedure in brief is as follows (see also chart on preceding page):

The juice, expressed from the cane by a crushing process is first subjected to a series of treatments in order to remove cane fibers and dirt, and various impurities, which include proteins, gums, and some of the minerals and acids present. With this accomplished, water is evaporated continuously from the juice until the desired quantity of sucrose has been precipitated. The remaining juice which surrounds these crystals, now called mother-liquor, is separated from the sucrose crystals by means of centrifugal machines, and this product is called *first-run or table molasses*.

This molasses still contains a considerable amount of sucrose; therefore, when so desired, the above process can be repeated—that is, more evaporation of water, a crystallizing out of a second “run” of sucrose, and a separation of the mother-liquor by centrifuging. The mother-liquor separated thus is called *second-run or cooking molasses*.

If this process is repeated with further separation of crystalline sucrose, a very dark sirup, called *black-strap molasses*, is produced.

Components of different grades of molasses. Obviously, the three grades of molasses contain decreasing quantities of sucrose. But they contain increasing quantities of other components that remain from the cane juice. These components include acids, substances with marked flavors, pigments, and iron compounds. Consequently, the three grades of molasses are increasingly stronger in flavor and increasingly darker, owing to the presence of both pigments and iron compounds.

Refiners' sirup. It has been noted previously that the raw sucrose from which molasses is separated is an unrefined product which contains many impurities including pigments, dark in color. Refinement of this raw sugar involves redissolving it in water and subjecting the solution to a processing as the result of which sucrose is eventually precipitated in the

white, crystalline form with which everyone is familiar. The mother-liquor that becomes separated during this procedure is called *refiners' sirup*; it is slightly dark in color and retains some impurities that were originally present in the cane.

Caramel. When any sugar, with no water present, is subjected to sufficiently high temperatures, a dehydration of the sugar begins to take place. With partial dehydration, intermediate products appear which are from yellow to brown in color and which vary in flavor from sweetish, to slightly bitter, to bitter. These intermediate products are referred to as *caramel* and the process is called caramelization. When dehydration of any portion of the sugar is carried to completion, the final solid product is carbon, other substances made, including water, having passed off in the gaseous state.

From sucrose. The caramel that is used in cookery is made from granulated sugar (sucrose). During its caramelization, under carefully controlled heating, a pale, straw-colored liquid appears which with further heating becomes brown and viscous, then a deeper brown. The dehydration should be carried only to the point at which the bitter product *just* begins to be made.

It is caramel produced thus from sucrose up to—but not beyond—the bitter stage which can be used satisfactorily to impart the desired flavor to certain food preparations. This “caramel” is a mixture of numerous substances.

Types of sucrose in use. Sucrose is the most widely used of the various sugars, both in the home and in industry. It is available in several forms as follows:

Granulated sugar is crystalline sucrose in which the size of individual crystals varies from larger crystals, such as are present in standard granulated sugar, to those smaller in size, as present in berry or fruit granulated sugar.

Powdered sugar is obtained by grinding granulated sugar. Consequently, this product contains broken crystals of sucrose of a considerable degree of fineness.

Confectioners' sugar is a still more finely ground prod-

uct in which sucrose crystals have been so pulverized as to have lost all appearance of crystal form. Because of its powdery texture this sugar has a tendency to "cake" in the presence of moisture, even that of moist air. Therefore, confectioners' sugar is usually blended with a small amount of either corn starch or powdered calcium phosphate in order to prevent the caking from taking place.

Loaf sugar, often called cube or domino sugar, is obtained by first permeating the granulated sugar with a warm concentrated sugar sirup, then pressing the mass into molds of desired form, and finally cooling it and evaporating the water. This type of sugar is usually served at table as a beverage accompaniment rather than finding any use in cookery.

Brown sugars are obtained during the process of refining cane sugar. They are separated from sirups from which some sucrose has already been crystallized. Therefore, brown sugars are made up of a somewhat smaller proportion of sucrose than are white sugars and a larger proportion of other components and cane juice.

These sugars are obtainable in various degrees of color which represent various degrees of refinement. For example: yellow sugar is the most refined of brown sugars, while light brown and dark brown sugars are the least refined of these products. Like molasses, brown sugars contain significant amounts of iron compounds.

SUCROSE CRYSTALLIZATION

One of the important uses of sucrose in cookery is in the making of candies and cake frostings in which it is the predominating ingredient. These products differ in flavor according to components, other than sugar, which are included. But they differ also in texture; and the texture of the candy or frosting depends to quite an extent: *first* upon whether the sucrose is present in crystalline or non-crystalline form; and, *second*, if present in crystalline form, upon the size of the

crystals. For example: the sucrose that is dispersed in caramels and brittle is non-crystalline; that in rock candy, fudge, and fondant is crystalline—coarse crystals in rock candy, fine crystals in fudge and fondant. And of cookery importance is the fact that the size of crystals—whether large or small—is influenced by technics used.

If crystals are to be large, technics must be such as (1) will insure the initial formation of relatively few nuclei when crystallization of sucrose begins to take place, and (2) will favor the continuing growth of these few nuclei to crystals of a size that is appropriate for the particular product involved.

If small crystals are desired, technics employed must be such as (1) will not only encourage the initial formation of numerous minute nuclei at the moment when sucrose crystallization begins to occur in the sugar sirup, but (2) will discourage their growth to crystals of any considerable size. A discussion follows of conditions obtained in sucrose sirups during cookery procedures and of technics to be employed toward obtaining products of desired texture.

Boiling temperature significant of sucrose concentration. To begin with, it should be emphasized that a sucrose solution of any given concentration has its own definite and specific boiling point, and that the greater the concentration of the sucrose solution the higher is its boiling temperature. These facts are exemplified in the accompanying table.

Boiling Points of Sucrose Solutions

Sucrose concentration	10%	30%	50%	70%	90.8%
Boiling point of solution	212.7° F.	213.8° F.	215.6° F.	223.7° F.	266° F.

It follows, then, that upon heating a given sugar and water solution it begins to boil at that definite temperature above 212° F. that is significant of the particular sugar concentration at the moment. It follows, too, that with continued boiling, as water

evaporates and the solution becomes more concentrated, the boiling temperature rises correspondingly. Finally, it follows that, with a sugar thermometer in the sugar solution, each boiling temperature level recorded is indicative of a definite sugar concentration. Hence, obviously, the boiling of the sugar solution can be stopped at the moment at which the sugar concentration has been obtained—as indicated by solution temperature—that is just right for the specific product concerned. Thus:

For some cake frostings the sugar concentration is just right when the boiling temperature of the sirup is 242° F.

For fudge the sugar concentration is right when the boiling point of the sirup is about 236° F.

Other means than dependence upon the temperature of the boiling sirup (as determined by use of a sugar thermometer) for arriving at desired sugar concentrations will be described later (p. 40).

Control of number of nuclei formed. When the proper sugar concentration is reached, the boiling sirup should be removed from the heat and allowed to cool, for a time, undisturbed. From this point on, it is the extent of the cooling that is permitted to take place, before the operator begins to stir the dispersion, that is the controlling factor which determines whether a few or many crystal nuclei will form.

If stirring is begun before cooling has been continued for very long, the number of nuclei that form as “seeds” for crystal growth will be relatively few. But if the sirup is cooled considerably before being disturbed, then upon stirring, numerous nuclear crystals will form. It follows, therefore, that if a coarsely crystalline product is desired, with crystals growing from relatively few nuclei, one should begin the stirring fairly early in the cooling process; but if a creamy product is desired, which calls for small crystals, the sirup should be allowed to cool considerably before stirring is begun.

Reasons for these technics. When the sirup is removed from the heat, it is an unsaturated solution. But in due time, as the dispersion is cooled, the solution attains saturation (p. 13), with all sugar still in solution. Upon further cooling below this

temperature, as long as the dispersion is not disturbed in any way which will cause precipitation of sucrose to occur, the solution at first is in a slightly supersaturated condition, but, as cooling continues, the sirup—again, provided it is not disturbed so that sucrose precipitation sets in—becomes progressively more and more highly supersaturated. (p. 16.)

Conditions for formation of few nuclei. If the sirup is stirred before it reaches a high degree of supersaturation—or if stirred when only at saturation, provided stirring is accompanied by gradual cooling—crystallization occurs slowly and only a few nuclei are formed.

Conditions for formation of many nuclei. On the other hand, if stirring of the sirup is delayed until, upon cooling, it has reached a high degree of supersaturation, the precipitation of sucrose takes place so rapidly that many minute crystal nuclei are formed all at once.

It follows, then, that if a creamy product is desired, the sirup should be allowed to become highly supersaturated before it is stirred; but when a coarsely crystalline mass is desired, the sirup should be stirred before it reaches this condition, either when it is saturated or when it is only slightly supersaturated.

Control of growth of crystals. Following upon the control of conditions which determine whether a few or many crystal nuclei form within the sirup, a control of *growth* of these crystals, as it affects the texture of the product, must be considered.

Formation of relatively large crystals. When the food product, such as rock candy, requires the formation of large sucrose crystals, the procedure is as follows: After the initial disturbance of the slightly cooled sirup, which gives rise to formation of relatively few crystal nuclei (p. 37), the crystallizing mass *from then on* should stand undisturbed in order to encourage the natural tendency of molecules, as they leave solution, to attach themselves to the few aggregates already present.

Insuring presence of many small crystals. But a food product of creamy texture calls not only for conditions which will lead to the formation of numerous crystal nuclei (p. 37), but also for conditions which will discourage crystal growth.

Two procedures toward accomplishing the latter end are: (1) *appropriate stirring* and (2) the introduction of an *interfering agent*. These effects are discussed briefly as follows:

The stirring factor. It will be recalled that for the initial formation of numerous small crystal nuclei the sirup should be cooled considerably, after removing from the heat, before the stirring is begun. But, for a product of creamy texture, this stirring, *once begun*, should be continued until crystallization is practically complete, a condition which will be obtained by the time the mass has approached room temperature and is at such a degree of stiffness that it is ready for pouring into its final shape.

The continued stirring is for the purpose of inhibiting the tendency of precipitating molecules to attach themselves to already existing molecule aggregates, thus forcing them, instead, to assemble in a greatly increased number of small crystals.

Introduction of an interfering agent. Substances present within a sugar sirup which are *interfering agents* are called thus because, by becoming concentrated on surfaces of small crystals of sucrose as they form, these agents "interfere" with the tendency of the small crystals to gather into larger aggregates.

These interfering agents include: materials as present in honey and corn sirup; finely dispersed fat of butter or cream; gelatin and the proteins of egg white and evaporated milk; and invert sugar. For the preparation of foods which require small sucrose crystals, one or more of these materials—invert sugar excepted—are customarily included among specified ingredients, and are incorporated with them at the beginning of the preparation procedure.

But the same procedure is not followed with invert sugar. Dependence for the presence of this interfering agent is placed upon producing it from the hydrolysis of a small portion of the sucrose during the boiling step in the preparation of the food product concerned—the candy or the frosting. However,

since sucrose hydrolysis proceeds very slowly without catalytic aid, it is the usual practice to provide hydrogen ions for catalyzing the reaction sufficiently to make enough invert sugar for the purpose desired. For providing these ions lemon juice, vinegar, powdered tartaric acid, or its acid salt, cream of tartar, can be used.

Non-crystalline products and interfering agents. In making creamy candies or frostings, just enough interfering agent should be present in the sirup to insure the formation of sucrose crystals of fine size, yet not so much as to prevent entirely the crystal formation of this sugar.

However, when a *non-crystalline* product is desired, such as caramels, nougats, and candies that are clear and hard, treatment of the sirup should be such as to prevent entirely sucrose crystallization from occurring. For such candies, recipes recommend the inclusion among ingredients of a larger proportion of evaporated milk, or cream, or corn sirup to act as interfering agent. As a consequence, since the sugar is unable to assemble in crystals, as the sirup cools it stiffens to form a continuous non-crystalline mass. The particular interfering agent that is advised depends upon the specific product that is desired.

The cold-water-ball test for sirup concentrations. It has been stated that different candies and frostings are made from sirups of different sugar concentrations and that the temperature of the boiling sirup, as determined by use of a sugar thermometer, serves as an indication of that concentration (p. 36). While this fact still stands, it is also true that the temperature which a sirup must attain to give the desired sugar concentration for any given product is influenced by the presence of ingredients other than the sugar (sucrose).

For some such mixtures the exact temperature when the sirup should be removed from the heat has been experimentally determined and is customarily included in the recipe for the particular product. But when this temperature is not

TEMPERATURES AND TESTS FOR SIRUP AND CANDIES²

Product	Temperature of sirup [at standard pressure (p. 7)] which is indicative of concentration desired		Test	Description of Test
	degrees F. 230 to 234	degrees C. 110 to 112		
Sirup			Thread	Sirup spins a 2-inch thread when dropped from fork or spoon.
Fondant } Fudge } Penuche }	234 to 240	112 to 115	Soft ball	Sirup, when dropped into very cold water, forms a soft ball which flattens on removal.
Caramels	244 to 248	118 to 120	Firm ball	Sirup, when dropped into very cold water, forms a firm ball which does not flatten on removal.
Divinity } Marshmallows } Popcorn balls }	250 to 266	121 to 130	Hard ball	Sirup, when dropped into very cold water, forms a ball which is hard enough to hold its shape, yet plastic.
Butterscotch } Taffies }	270 to 290	132 to 143	Soft crack	Sirup, when dropped into very cold water, separates into threads which are hard but not brittle.
Brittle } Glacé }	300 to 310	149 to 154	Hard crack	Sirup, when dropped into very cold water, separates into threads which are hard and brittle.
Barley sugar	320	160	Clear liquid	The sugar liquefies.
Caramel	338	170	Brown liquid	The liquid becomes brown.

² Handbook of Food Preparation, American Home Economics Association, Washington, D. C., 1946, p. 45.

known, also when the cook is proceeding without the use of a thermometer, the familiar *cold-water-ball test* is resorted to for arriving at the just-right sugar concentration.

This test calls for dropping a small amount of the boiling sirup into cold water and allowing it to remain for about a minute. At the end of this time the ball formed is removed from the water and its firmness is tested. The accompanying table lists different candies and describes the character of the ball that should be formed at the correct sugar concentration for each product.

This table also lists a boiling temperature *range* within which the sirup attains the sugar concentration necessary for each product. A temperature range is given in order to allow for the effect that varying composition of the sirup may have upon the specific temperature at which a ball of given consistency is formed. For example, when a sucrose sirup contains corn sirup, a ball of given consistency is formed at a lower temperature, while a sucrose sirup that contains invert sugar forms a ball of this same consistency at a higher temperature than would be the case with a ball obtained from a sucrose-water sirup without the presence of either of these interfering agents.

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CHAPTER IV

STARCH AND STARCH COOKERY

Types of starches. The chief commercial source of starch is the seeds of grains, but important amounts are also obtained from roots, tubers, and fleshy stems of a variety of plants.

Cornstarch. Among seeds, corn is preëminent in supplying the bulk of food starch that is used in this country. This corn product is commonly known as *cornstarch*. It is used as a thickening agent for various food preparations such as gravies, soups, and many desserts.

Tapioca. This is the name that is applied to the type of starch obtained from the cassava plant, grown extensively in most tropical regions of the world. The plant has a large fleshy root permeated with a milky juice which is largely a starch-in-water dispersion. The chief use of tapioca is as a thickening material for fruit juices and for milk in the preparation of a variety of desserts.

Arrowroot starch. This starch is obtained from fleshy underground stems (tubers) of several different tropical plants. Like tapioca, arrowroot starch is used to some extent in making various desserts.

Sago starch. Sago starch is formed in the pith of stems of the sago palm which is grown in the tropics.

Starch granules. All starches are distributed in plants in the form of tiny grains or packages called *granules*, these differ in size and shape according to plants in which they are assembled (Fig. 4).

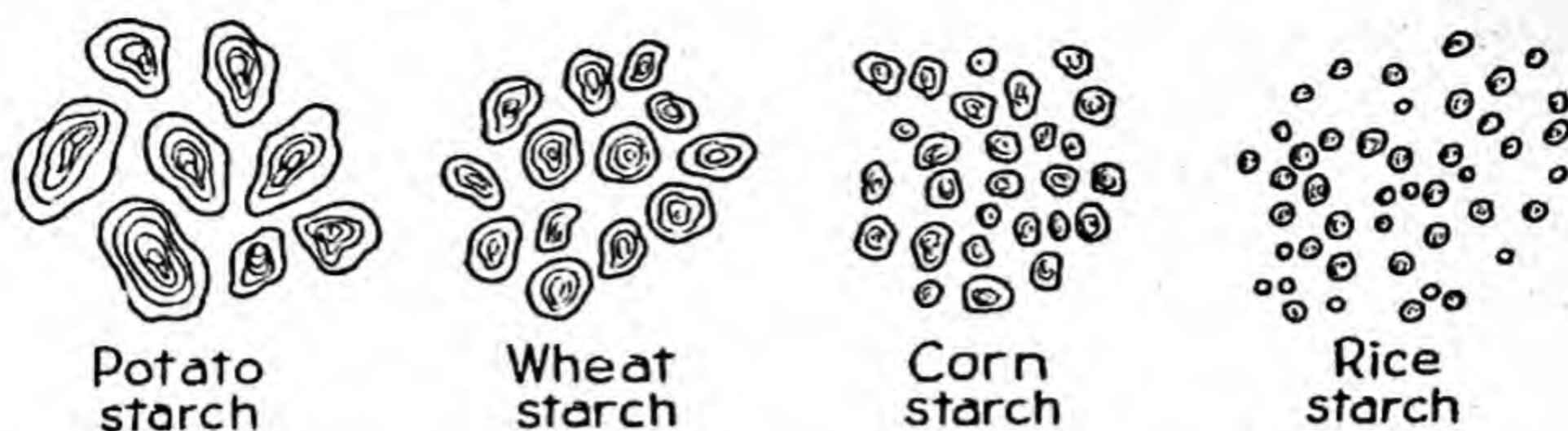


Fig. 4. Diagrammatic suggestion of starch granules from several plant sources.

Two different kinds of starch molecules are contained in most starch granules. They are called, respectively, *amylopectin* (sometimes referred to as alpha-amylase¹) and *amylose* (sometimes designated as beta-amylase), and it is believed that the difference between them is due to a difference in the manner in which glucose radicals are combined within their respective molecules.²

The structure of the starch granule,³ probably much the same for granules of all starches, has been a subject of research by starch chemists for many years, but, as yet, its exact pattern has not been conclusively established. However, it is believed that the granule structure follows a more or less consistent and orderly scheme as follows: *first*, presumably the starch granule as a whole is made up of similar *structural units*, oriented radially in respect to one another around a common center, and held in place by some sort of easily severed bonds; *second*, each structural unit is believed to be composed of many molecules of amylopectin and amylose in mutual but loose combination (Fig. 5).

Starch as a thickening agent. An important function of starch in cookery is as a *thickening agent*. The thickening

¹ The term amylose is derived from the Latin name for starch, which is *amylum*.

² Hassid, W. Z., "The chemistry of the carbohydrates," *Annual Reviews of Biochemistry*, Vol. 13 (1944), pp. 59-92.

³ Alsberg, C. L., "Structure of the starch granule," *Plant Physiology*, Vol. 13 (1938), pp. 295-330.

action, presumably, is due to the ability of the numerous granules to swell to many times their original size when in hot water; in so doing, they crowd each other and more or less fill the space throughout the dispersion.

Gelatinization.⁴ This swelling of starch granules in hot

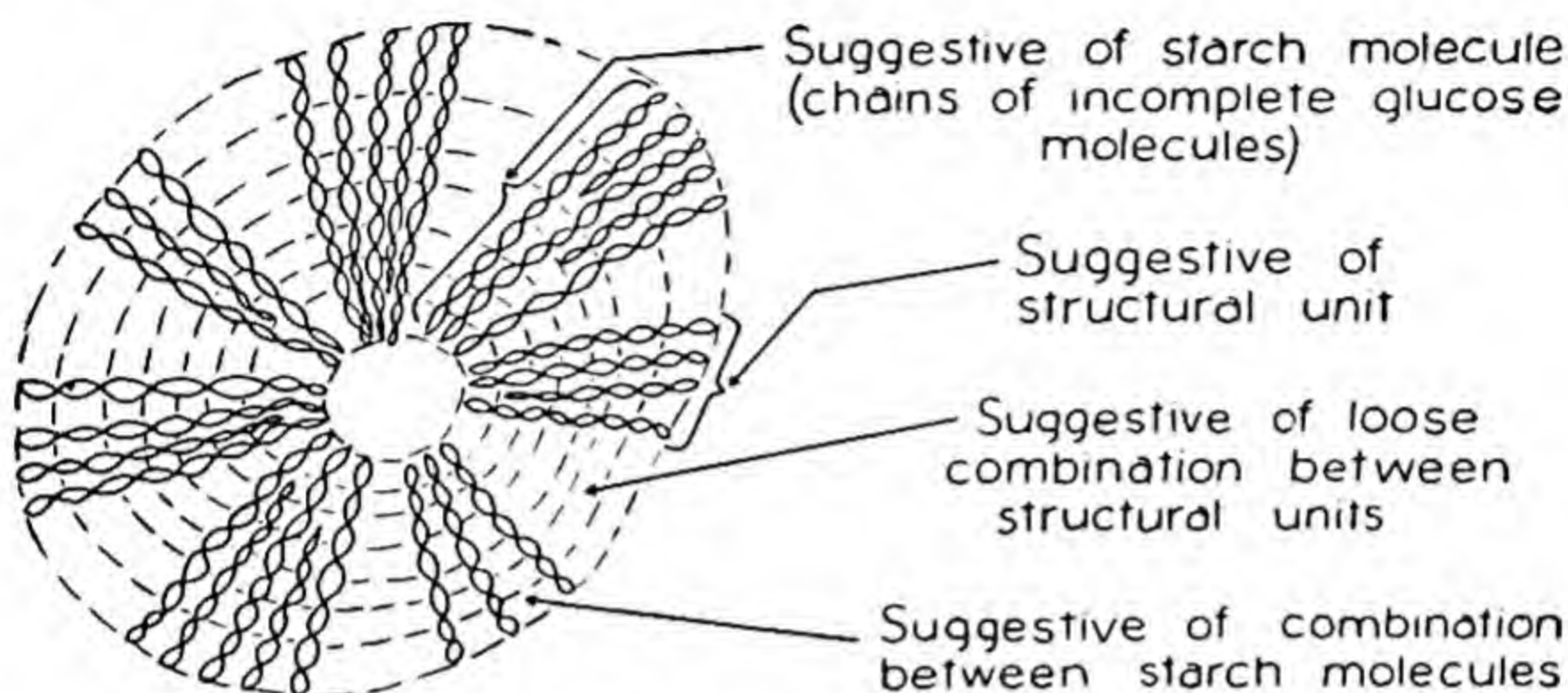


Fig. 5. Diagrammatic suggestion of structure of a starch granule.

water is called *gelatinization*. It takes place gradually as the temperature of the dispersion is raised and it is made evident by the gradual thickening of the product.

Explanation: It has been said that the structure of the starch granule is not at present clearly understood. It is true, also, that there is no entirely satisfactory explanation of the changes that take place in the granule structure during the process of gelatinization. It is postulated, however, that hot water upon entering the granule first weakens forces between unit structures (Fig. 5), then penetrates each of these structural units, where it causes a greater or less separation of the many starch molecules from each other through releasing bonds between them. This causes a considerable swelling of each structural unit and the effect is repeated for all the many units that comprise a single granule, thereby accounting for the enormous increase in size of the granule as a whole when in hot water.

⁴ Caesar, G. V., and Cushing, M. L., "The starch molecule," *Journal of Physical Chemistry*, Vol. 45 (1941), pp. 776-790.

Bear, R. S., and Samsa, E. G., "Gelatinization mechanism of starch granules," *Industrial and Engineering Chemistry*, Vol. 35 (1943), pp. 721-726.

As gelatinization proceeds, with continued heating of the starch dispersion, some of the swollen granules apparently disintegrate into fragments of various sizes, and it may even be possible that some of the contained amylopectin and amylose molecules are released to become colloiddally dispersed particles.

Components of final dispersion. According to the extent to which these changes in the granules have been carried, the final components in any gelatinized starch dispersion are: (1) mostly swollen starch granules and (2) some relatively large granule fragments—both held in suspension, with (3) smaller granule fragments and (4) some amylopectin and amylose molecules held in colloidal solution. But it is probable that of these several components the swollen, unruptured granules are chiefly responsible for the thickening of the dispersion.

PREPARATION OF THICKENED STARCH DISHES

The use of powdered starches. In all thickened products in which a powdered type of starch—such as corn or arrowroot starch or a wheat flour—is used as the thickening agent, a smooth, velvety texture is desired. In order to obtain this quality each starch granule should gelatinize independently of every other granule, insofar as is possible. Toward this end, granules must be more or less separated from each other before they are brought into contact with the hot liquid.

Separating agents. The materials used for separating agents are: a cold liquid or melted fat in the making of ordinary sauces and gravies, and sugar when making sweetened sauces and puddings. Following the initial separation, the mixture should be stirred constantly as it is heated, in order both to maintain the separateness of starch granules and to establish an even distribution of granules as they gelatinize.

To achieve good flavor. Complete gelatinization of the starch is probably obtained by the time the mixture has been heated to approximately 195 to 205° F. Even so, in most

cases a more agreeable flavor results if a sauce or pudding is allowed to reach its boiling temperature and is held there for about a half-minute. If preferred, however, the product may be cooked over boiling water, in which case the mixture cannot in itself be brought up to this temperature. Therefore, under this condition the pudding or the sauce should be kept at the lower temperature for a longer time in order to insure maximum palatability.

To obtain desired thickness. In cookery, starch products of different degrees of thickness are desired according to the use for which they are intended. The right degree of thickness in any instance is arrived at by adjusting the proportion of starch—provided by wheat flour, cornstarch, etc.—to the liquid ingredient called for in the recipe.

Cooling and thickness. When a starch paste is allowed to cool, the mass becomes increasingly thicker. If the starch content is high enough, a product is made possible which is more or less rigid and can be molded, an effect that is made use of in making molded desserts such as cornstarch puddings. But for other products the thickening of starch paste, upon cooling, is frequently disconcerting; this is the case with gravies and creamed dishes which often become too thick as they cool during the progress of a meal. It follows that this property of a starch paste should be taken into consideration and allowed for in initial starch-to-water measurements.

Skin formation. As a final step in the technic of starch cookery, the product should be covered whenever it is necessary to hold it for later use. Should this precaution not be observed, evaporation of water will occur and a skin⁵ will form over the surface. This skin is frequently responsible for lumps in sauces and creamed soups which are thereby rendered considerably less appealing. If the product is a

⁵ The skin is attributed to a reversal on the part of *amylose* to a less dispersible form and its consequent precipitation from the dispersion. In this behavior the starch is said to have "retrograded." Schoch, T. J., "Physical aspects of starch behavior," *Cereal Chemistry*, Vol. 18 (1941), pp. 121-128.

molded pudding, the skinned-over surface can be covered with a garnish or the pudding can be unmolded in such a manner that this surface rests on a plate.

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CHAPTER V

GRAINS, BREAKFAST CEREALS

GRAINS

Food materials classed as grains include the edible seeds of certain grasses. From a world viewpoint, the six important grains are wheat, corn, rice, barley, oats, and rye; and one or more of these provides a staple article of diet of every nation in the world. Among the food products manufactured from these grains are breakfast cereals; alimentary pastes, including such foods as macaroni; flours and breads.

Historical items. The history of world civilization is intimately bound up with the cultivation of grains. It is said that when the early wandering tribes acquired a knowledge of the desirability of certain seeds as foods, they ceased their nomadic existence and settled in communities where they found the best conditions for the cultivation of the grasses concerned.

Since these conditions prevailed chiefly in the fertile valleys of rivers, it has become possible to trace the history of the cultivation of the several grains through the records left by people who settled in these regions. In this manner the history of the raising of *wheat* is traced to the fertile valleys of the Tigris and Euphrates rivers in Mesopotamia, and along the southeastern shores of the Mediterranean; of *barley* to the valleys of the river Nile in Egypt; and of *rice* to the low-land river valleys of China.

Oats and *rye* are of somewhat later cultivation and are associated with the more northern areas of Europe and Asia.

Corn is the only grain indigenous to the Americas, where it is believed to have been grown in prehistoric times in Central America.

Origin of the word cereal. Although in these modern times the term cereal is commonly associated chiefly with breakfast cereals, originally it had a larger use in reference both to grains and to the grasses which produce them. The origin of this word goes back to ancient Rome and the goddess Ceres, whom the Romans worshiped as the giver of grains and in honor of whom a great festival was held annually when wheat and barley were harvested.

Oats, barley, and rye. In the United States, these three grains are of less consequence by way of providing foods for human consumption than are the other grains mentioned; but they do have some valuable uses.

Oats. In this country this grain is processed for the manufacture of breakfast cereals; but of greater importance is its function as a food for livestock.

Barley. This grain also serves for livestock feeding, but a more extensive use is in the fermentation industries for the making of such beverages as beer and ale.

Rye. Of the six grains discussed here, rye is of least importance in production figures as to growth in the United States. It is used to some extent in this country for livestock feeding. For human consumption, in the form of flour, it is usually mixed with wheat flour to make rye bread.

In other parts of the world, however, especially in Russia, in Central Europe, and in Scandinavian countries, rye is greatly valued as a food for humans. In these countries it is used with wheat as a bread grain.

Corn. This cereal constitutes the most important grain crop in the United States where, in acreage planted, amount of grain produced, and money value, it ranks ahead of all other grains. In fact, the United States produces more than one-half of the corn grown in the world as a whole.

Although corn is produced in every state in this country,

it is grown most extensively in the so-called corn belt. This region lies in the Mississippi valley extending approximately from southern Minnesota and southeastern South Dakota to northern Missouri—a section of the country in which hot summers with warm nights provide favorable conditions for the growth of this grain.

Uses. Much of the corn crop in the United States is needed on the farms or in the localities where it is grown, since its principal use is as a food for livestock. For this purpose it is of greater importance than either oats or barley.

For human consumption, corn is processed for the manufacture of breakfast cereals, such as cornmeal and cornflakes; and, to some extent, for the making of cornstarch. Corn oil, corn sirup (p. 30), and corn sugar (p. 31) are other food products derived from this grain.

Corn has many uses in non-food industries which add greatly to the over-all value of the crop. But it is with its food use that this text is concerned.

Wheat. *Where grown.* Wheat is one of the most widely cultivated of grain crops. Since the plant can adapt itself to a great variety of climatic and soil conditions, it is grown to some extent in every country in the world, tropical regions excepted.

Wheat was introduced into the western hemisphere by the Spaniards, who brought the seed to Mexico. In the United States it was grown by the colonists along the eastern seaboard early in the seventeenth century, and from these regions its cultivation spread throughout the country as frontiers were pushed westward. Today, the cultivation of wheat in this country has become so widespread—especially in the great plains areas, which provide excellent conditions for the growth of this grain—that its production in the United States ranks second only to that of corn in acreage planted. It should be emphasized, however, that the introduction of large-scale harvesting and threshing machinery and modern roller-

milling methods for flour production has contributed vitally to this development.

The great wheat-growing areas in the world are: the Pacific Northwest and the great plains of the United States, Canada, and Argentina; southern Russia and the Danube basin; the Mediterranean countries and northwestern Europe; northern India and Australia. Of these countries, only the United States, Canada, Argentina, and Australia produce more wheat than is needed for their own domestic uses. These four countries, then, are the wheat-exporting countries of the world; while those countries that must import wheat include Great Britain, Ireland, Italy, Germany, France, and Belgium.

Uses. Since wheat is the chief bread grain of the world, enormous quantities are milled into flour for the making of this food product. Wheat is extensively used, too, for the manufacture of breakfast cereals.

Like other grains, wheat serves to some extent for livestock feeding. It also has many industrial uses.

Rice. This grain is the principal food crop of about one-half the population of the world. It is a staple article of diet in parts of China, in India, Java, and Japan, all of which countries are densely populated. Crop-growing conditions for this grain in these countries are sufficiently favorable so that, normally, they are able to raise enough rice to meet their own food requirements.

While in the United States rice is of less importance than either corn or wheat, considerable acreage is nonetheless devoted to the raising of this grain. Its cultivation requires a hot, moist climate and a soil which can be flooded and will retain water for long periods of time. These conditions prevail in some sections of California, Louisiana, Texas, and Arkansas; hence it is in these states that almost all of the rice produced in this country is grown.

Brown and white rice.¹ *Brown rice* is essentially the

¹ For types of enriched rice, see p. 58.

entire kernel, since only a small portion of bran (Fig. 6) becomes separated when the chaffy hull, which originally envelops the seed, is removed. *White rice* is often called polished rice. In removal of the bran and germ by procedures called scouring and polishing, the kernel becomes white and slightly polished.

Uses. For the sake of variety in menu planning rice is sometimes used in place of potato. Various desserts are also

made which include rice as the main component.

Structure and composition of the grain kernel.

As said previously (p. 49), it is the seed or kernel of the grain grass that is used for food purposes. Although kernels differ as to size and shape, according to their plant source, they are all composed of the same structural parts and food nutrients. Further-

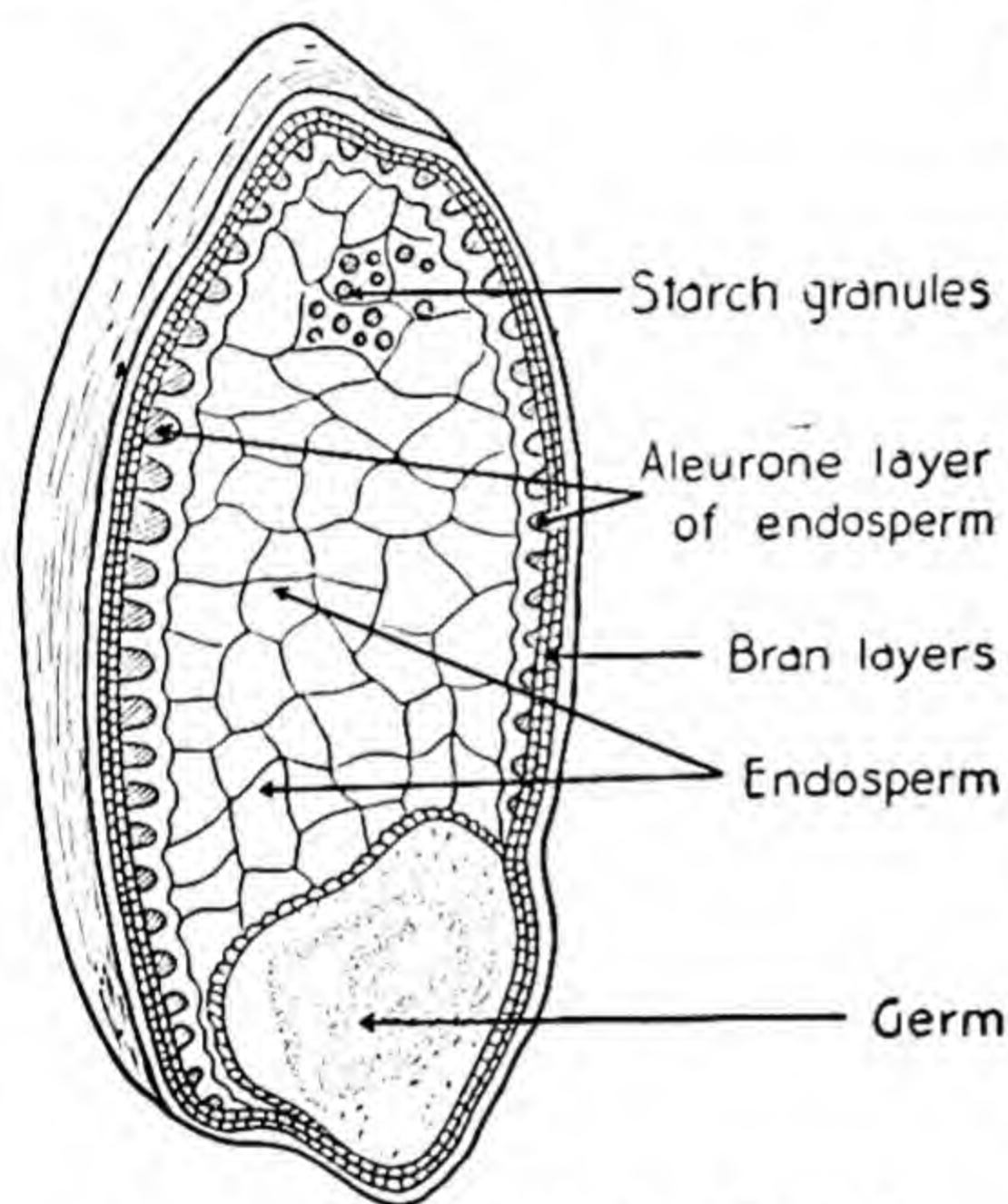


Fig. 6. Structure of wheat kernel.

more, in general, they resemble each other in the way in which these nutrients are distributed. A discussion follows of important structural parts and general features of kernels of all grains—the student is advised to follow the discussion with constant reference to the diagram given, in which the wheat kernel is used as typical (Fig. 6).

Bran. The outer protective covering of the kernel is the *bran*. It consists of several thin layers which are chiefly

cellulose, but are relatively rich in proteins, minerals, and vitamins (see table, p. 55).

Endosperm. The endosperm comprises much the greater part of the kernel, approximately 84 to 85 per cent, and it is here that nature stores the reserve food supply, mainly starch, to be held in readiness for the time when the seed begins to germinate into a new plant. With the exception of its aleurone layer (see below) the endosperm is composed of thin-walled cells which contain starch granules embedded in a protein matrix. While in these cells starch predominates, there is an important amount of protein present, also traces of minerals and vitamins.

The *aleurone layer* of the endosperm is the name given to its outer portion, meaning that layer which lies just within the bran. It is usually characterized by a single row of more or less cubicle cells. These cells are devoid of starch, but they contain fat and a high proportion of proteins, minerals, and vitamins.

Germ. This is the part of the seed which holds the rudiments of the new plant. It lies at one end toward the side of the kernel, embedded in the endosperm and covered by protecting bran layers. The germ contains proteins and is especially rich in minerals, vitamins, and fats. Like the bran and the aleurone portions of the endosperm, the germ does not contain starch.

Unrefined and refined grain products. Why two varieties of products are possible. The natural division of the grain kernel into clearly defined structural parts, each differing from the others in respect to the foodstuffs which it contains, has an important bearing upon the composition, and therefore upon the nutritive value, of the various products—breakfast foods and flours—milled therefrom.

This must be the case, since in the milling of grains for the manufacture of grain products there are, in general, two different procedures:

1. Sometimes the entire kernel is retained intact. Usually, however, it is crushed and the milled portions reblended—but

SUMMARY OF COMPONENTS OF WHEAT KERNEL

<i>Endosperm</i>	<i>Bran</i>	<i>Germ</i>
Chiefly starch (aleurone excepted)	Mostly cellulose	Proteins
Cellulose (cell walls)	Rich in proteins	Rich in mineral elements: phosphorus, iron ²
Proteins	Rich in mineral elements: phosphorus, iron ²	Rich in vitamins: thiamine, riboflavin, niacin
Traces of mineral elements	Rich in vitamins: thiamine, riboflavin, niacin	Fat
Traces of vitamins		
<i>Aleurone layer</i>		
No starch		
Some fat		
Rich in: proteins mineral elements vitamins: thiamine, niacin, riboflavin		

with all the structural parts of the kernel present in the products.

2. In other processing methods the structural layers of the crushed kernel are mechanically separated in such a manner that only the endosperm parts comprise the grain product; or, in some products, the endosperm and some of the bran layers.

Unrefined grain products. When all of the structural parts of the kernel are retained in the processed grain, the products are designated as *whole grain or unrefined*. And, obviously, these grain products—breakfast cereals or flours—contribute the same foodstuffs to the diet as would the original unmilled kernel, namely: cellulose and starch, proteins, fats, minerals, and vitamins. Hence the nutritional value of such products is at maximum.

² Calcium, potassium, copper, and manganese are also present in appreciable quantities. Excepting potassium, all mineral elements are present in higher proportion in bran than in germ.

Refined grain products. Refined products are in contrast to unrefined grain products, since the former, *made only from the endosperm* of the kernel, contain chiefly starch and proteins, with considerably less quantities of minerals and vitamins. Therefore, these refined grain products are of value, nutritionally, mainly for their starch and protein components.

Intermediate products. Finally, under some processing methods, products of an intermediate degree of refinement are made. This is accomplished by rejecting only the *outer* bran layers and the germ. The resulting grain products, then, which contain *only the inner bran layers and all of the endosperm*, are less coarse in texture than those of the whole-grain or unrefined variety; and, since they lack the fat component of the germ, their keeping quality is better. Nutritionally, these intermediate grain products have the important advantage over those of the refined variety in their superior mineral and vitamin content, as well as in the superior quality of proteins, contributed by the bran layers included.

ENRICHMENT OF GRAIN PRODUCTS

Definitions. *Enriched flour* is refined wheat flour to which mineral *iron* and the vitamins *thiamine*, *riboflavin*, and *niacin* have been added in such amounts as to restore these nutrients to the approximate levels originally present in the wheat kernels from which the flour was milled. Any flour for which "enrichment" is claimed *must* contain these added nutrients. Calcium and vitamin D in specified quantities also *may* be added to enriched flour, but unlike the several B-vitamins and iron their inclusion is optional on the part of the manufacturer concerned. *Enriched bread* is *white* bread which contains, in addition to the usual ingredients, appropriate amounts of the vitamins and iron as specified above for enriched flour.

Methods of enrichment. *Flour* is usually enriched by feeding into the final flour stream, that is obtained from the milling of the wheat, a stream of enrichment mixture in such a quantity that the resulting flour will contain the required proportions of the added nutrients.

Bread may be enriched in several ways as follows: (1) it may be made of enriched flour; (2) a vitamin-mineral mixture may be incorporated into the dough in the mixing process; (3) enriched bakers' yeast may be used instead of ordinary yeast, this yeast having been cultured in such a way as to be high in thiamine content and augmented by the addition of other requisite vitamins and by iron.

Enrichment policy. The initial step in the program of enrichment of white flour and bread, and of other processed cereal products, was taken by the Council on Foods and Nutrition of the American Medical Association. This Council, in 1939, adopted a resolution quoted in part as follows: "... to encourage the restorative addition of vitamins or minerals or other dietary essentials, in such amounts as will raise the content of vitamin or mineral or other dietary essential of general purpose foods to recognized high natural levels; with the provision that such additions are to be limited to vitamins or minerals or other dietary essentials, for which a wider distribution is considered by the Council to be in the interest of the public health."³

From this beginning, through the cooperative efforts of certain government agencies and of associations that are representative of the milling and baking industries, the program developed so rapidly that actual production of enriched flour and enriched bread was begun by some manufacturers in the spring of 1941.

The entrance of the United States into World War II gave added impetus to the proposed program for obtaining enriched flour and bread, with the result that in January 1943, under War Food Order No. 1, the enrichment of all bakers' *white bread* became mandatory; and in 1944 this order was amended to include all *plain varieties of white rolls*. But these mandatory provisions for enrichment of various breads were canceled in 1946. At no time during the war years, or since, was enrichment of *flour* compulsory.

³ Wilder, R. M., and Williams, R. R., *Enrichment of Flour and Breads*, National Research Council, Washington, D. C., Bulletin No. 110 (1944), p. 20

Such is the status of federal law, or lack of law, in regard to enrichment today. However, several states have passed legislation for mandatory enrichment of all white flour and white bread sold within their borders. It is to be hoped that, in the interest of better nutrition for all levels of the population, all states will take similar action. In the meantime, wherever such a law is not in effect, it becomes the responsibility of the individual buying white flour and bread to find out from information provided on package labels whether the enclosed flour or bread is enriched.

Why the emphasis on enrichment of grain products.

In regard to the enrichment of foods it has been the expressed policy of the several agencies concerned that such enrichment should be limited to foods that constitute staple articles of diet for large segments of the entire population. It is for this reason that emphasis is placed upon enrichment of flour, bread, and other cereal products, since these are staple, day-to-day foods of people in all income brackets. Moreover, enrichment of these particular products is of special significance for people in low-income brackets since, owing to the comparatively low cost of these foods, they comprise a large portion of the every-day diets of this vast majority group.

Enrichment of other cereal products. Cereal products, other than white flour and white bread, that are sometimes enriched include refined breakfast cereals, degerminated cornmeal, polished rice, and macaroni and spaghetti. The enrichment of cornmeal and rice is discussed in the following sections.

Cornmeal. Cornmeal is a staple food in the southern part of the United States. The corn kernel in itself is low in niacin content; furthermore, if this kernel is degerminated in processing—as is frequently the case—the resulting meal suffers a loss in B-vitamins, other than niacin, and in minerals. Fortunately, at the present time, several of the southern states have legislation which makes enrichment of degerminated cornmeal compulsory; but in most states enrichment of this cereal is voluntary with the manufacturers.

Rice. Doubtless the impetus to the study of ways and

means for securing a pleasingly edible rice product, which will retain a large portion of the nutrients of the unmilled kernel, has come from two sources: (1) a realization that the malnutrition prevailing among people in oriental countries is directly related to the use of the traditionally milled form of rice (polished rice) which constitutes their chief article of diet; and (2) a growing world-wide interest in the improvement of the nutritional condition of all peoples of the world.

The problem of obtaining a satisfactory rice cereal lies in a modification of milling procedure which will provide for the retention of considerable portions of the bran and aleurone layers of the rice kernel where minerals and the vitamins thiamine, riboflavin, and niacin are chiefly located. Two products so obtained are called: (1) undermilled or unpolished rice and (2) converted rice.

Undermilled or unpolished rice. This "enriched" rice is obtained by omitting from the usual milling procedure the final polishing step; as a result, in the refined rice product the milled kernel retains some of its bran and aleurone layers. Unpolished rice is only slightly darker than polished rice and it is substantially richer in thiamine, riboflavin, niacin, and minerals.

Converted rice. The production of this type of rice product involves an adaptation of a parboiling process that has long been in use in India. Briefly the procedure is as follows:⁴

Rough rice or "paddy" (kernels with outer hulls attached) is placed in large cylinders which are air-evacuated; after about 10 minutes hot water is introduced under a pressure of from 80 to 100 pounds per square inch and the rice is steeped for several hours; the water is then drained off and the paddy is heated in rotating, steam-jacketed cylinders under a partial vacuum until the moisture content of the kernels is approximately 15 per cent. After this preliminary

⁴ Kik, M. C., and Williams, R. R., *The Nutritional Enrichment of White Rice*, National Research Council, Washington, D. C., Bulletin No. 112 (1945).

“conversion” treatment, the hulls are removed and the kernels are scoured and polished in the traditional manner to give *polished converted rice*. Despite this final treatment the kernels retain a larger-than-usual portion of the bran coats, hence a large portion of minerals and vitamins that were originally present in the rice. Moreover, it has been suggested that during the steeping process some vitamins and minerals may even diffuse from outer layers of the rice kernel into the endosperm.

Artificially enriched rice. This is a mixture of polished rice with a small amount of a “fortified premix rice.” The latter is made by impregnating rice kernels with a concentrated solution of the enrichment foodstuffs; the enriched kernels are then coated with a film of edible material that protects the added nutrients from solution in water during the rinsing of the kernels, rinsing being the usual preliminary step in the cooking of rice.

A caution in rice cookery. In cooking enriched rice it cannot be emphasized too strongly that only such a quantity of water should be used as can be absorbed by the kernels during the cooking period. This is in contrast to a method frequently employed in which so much water is used that a considerable amount remains to be drained away after cooking is completed. In this latter method, irrespective of the type of rice being cooked, there is obviously an unnecessarily large loss of soluble nutrients, owing to their being leached out into the water and discarded with it.

Packaged rice is a clean product and does not need to be washed prior to cooking; rice purchased in bulk should be thoroughly washed.

BREAKFAST CEREALS

Breakfast cereals constitute a large and very important class of grain products. Some type of cereal often forms the central dish around which the rest of the breakfast is planned. In fact, a serving of cereal and milk, together with a bread

(toast or muffins) and butter, a fruit or fruit juice, and a beverage, comprises a usual breakfast which contributes its needed share to the daily food requirement.

Some representative cereals. Breakfast cereals in common use and items concerning them are as follows:

Hominy or corn grits. This is the coarsely ground endosperm (Fig. 6) of corn.

Cornmeal, old process. For this product the entire corn kernel is ground between rotating stones. In some cases a small amount of the coarsest bran and some of the germ may be subsequently removed by screening through bolting cloth. This cereal is sometimes called water-ground cornmeal, due to the fact that water power is often used for the grinding process.

Cornmeal, new process.⁵ To make this cereal, the corn kernel is ground between steel rollers. The germ and most of the bran are removed; also some of the more starchy portions of the endosperm are frequently separated for the making of *corn flour*.

Cornflakes. This is a ready-to-eat cereal, having received heat treatment during processing. It consists of corn grits which have been rolled, after the addition of various ingredients according to the particular manufacturer's formula for this product.⁶

Puffed cereals. These are ready-to-eat cereals in which the kernels are heated under pressure. Then, when pressure is released, hot air and vapor, previously held captive within the kernels, expand explosively, thereby causing the puffing-up of the grains.

Rolled or flaked cereals. In the manufacture of these cereals, the entire kernels, softened by steam, are passed between rollers in order to flatten them into flake-like shapes. In some products the kernels are cut into several pieces before

⁵ For enriched cornmeal see page 58.

⁶ The usual practice on the part of manufacturers is to enrich this type of cereal with iron and the vitamins thiamine and riboflavin.

being subjected to the rolling process in order to make quick-cooking cereals.

Farinas. These are wheat cereals which are made by “cracking” the wheat endosperm into the small particles that are characteristic of this grain product. In some processings, finer particles are separated by screening in order to obtain quick-cooking farinas.

Classification. Breakfast cereals can be classified from three different angles as follows:

1. As to **nutritive value**, these cereals, like all grain products (p. 54), are classed as *whole-grain or unrefined* and *refined*. The various rolled oats are examples of whole-grain breakfast cereals, while farinas exemplify those of the refined variety. The relative food values of these two types of cereals have already been presented (p. 55).

2. From the viewpoint of **preparation for serving**, cereals are classed as *uncooked* and *ready-to-eat*. These classifications are exemplified by rolled oats and cornflakes respectively. Ready-to-eat cereals, as their name implies, are completely cooked during their manufacture and are ready to serve just as they come from the package.

3. As to **methods of cooking**, breakfast cereals, excepting only the ready-to-eat types, are classed according to the final physical form of the kernels resulting from the manufacturing process. From this angle these cereals fall into two categories: *flaky type cereals*, in which the grain kernels—either whole or in pieces—have been flattened into flakes between rollers; *granular cereals*, in which kernels have been mechanically divided until the individual particles are very small and round, resembling those of a meal. Flaked wheats and rolled oats illustrate flaky type cereals, while hominies and farinas are representative of the granular type.

How these physical characteristics affect cereal cookery is discussed in the following section.

Cereal cookery. Object. The object in cooking breakfast cereals is to soften the cellulose, cook the proteins and starch, and develop flavor.

Since *starch* is the foodstuff present in largest amount, the attention in cooking is centered chiefly on this component; and the process is one of gelatinization (p. 45) of the starch granules which are embedded in the pieces of cereal. There is considerable difference of opinion, with personal preference as a basis, as to the length of time that is most desirable for cereal cookery. By some, a cooking period of several hours, such as overnight, is thought to bring out what the supporters of this procedure call a nut-like flavor. Others claim that the softening of cellulose by moist heat is carried too far through such long cooking, as a result of which the quality of the cereal is claimed to be impaired and its palatability lessened.

When considered from an actual scientific angle, however, a cereal is cooked when the starch is completely gelatinized. And there is experimental evidence to indicate that, for granular cereals at least, this is accomplished when the cereal is boiled over direct flame for one or two minutes, followed by cooking over boiling water for an additional fifteen or ten minutes respectively.⁷ As for *proteins* present, such limited alterations as ever take place during cooking in respect to this class of foodstuffs have also been achieved during this shorter time period. Consequently, any extension of cooking time beyond this period becomes a matter of personal preference and applies chiefly to the degree of softening of the cellulose that is desired.

These cooking times do not apply to the quick-cooking cereals, for which, obviously, shorter periods are adequate.

Methods of cooking breakfast cereals. During the cooking procedure, all pieces of cereal, each of which contains many embedded starch granules, must be kept separate from neighboring pieces so that water is able to penetrate to the granules in order to gelatinize them. A clumping to-

⁷ Hughes, O., Green, E., and Campbell, L., "The effect of various temperatures and time periods on the percentage of gelatinization of wheat and corn-starch and of cereals containing those starches," *Cereal Chemistry*, Vol. 15 (1938), pp. 795-800.

gether of pieces of cereal is thus avoided and the finished product will be free from lumps.

This separation is accomplished by pouring the cereal, such as rolled oats or hominy, into rapidly boiling water—while stirring constantly—so slowly that the boiling does not cease at any time during the process. Or, for finely granular cereals, such as cornmeal, an alternate method can be used in which the cereal, mixed with a portion of the measured amount of cold water, is poured slowly and with constant stirring into the remainder of the water, which is rapidly boiling.

Proportions of cereal to water that are satisfactory in cooking these two types of breakfast cereals are as follows:

1 part flaky cereal, 2 to 3 parts water.

1 part granular cereal, 4 to 6 parts water.

1¼ teaspoonfuls of salt for each quart of water used.

A considerable *range* as to quantity of water is allowed for, since personal preferences vary in regard to the degree of firmness desired in the cooked product. As should be anticipated, in general, a smaller proportion of water is necessary for the flaky than the granular type of cereal; also it is true that various cereals, even of the same type—flaky or granular—frequently differ in the amount of water they absorb in giving cooked products of the same consistency.

Characteristics of cooked cereal. The cooked cereal, when ready to serve, should have a pleasant flavor; the cellulose should be more or less softened as to texture; the cereal should be free from lumps, and of such a consistency that it will barely pour from the kettle.

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CHAPTER VI

WHEAT FLOUR, ROLE OF GLUTEN

Flour is the most important grain product that is manufactured from wheat. Moreover, the fine white flours for which there are so many cookery uses today are vastly different from the coarse wheat meals of ancient days; just as different, in fact, as the modern flour mill, with its intricate machinery, is from the crude milling devices of former years, which consisted chiefly of stones between which the wheat kernels were crushed.

Milling of flour. The object of the modern milling of wheat, as with other grains, is not only to crush the kernels but to separate their various parts (Fig. 6): the *bran* which is flaky and tough, especially the outer layers; the *endosperm*, which, being crumbly, is more or less easily powdered, save for the outer *aleurone layer* which clings to the bran; and the *germ*.

Briefly, this is accomplished by passing the kernels between a succession of five or six pairs of steel rollers. The crushed product, called a "break," that emerges from each pair of rollers is sorted mechanically into three portions: (1) fine flour, called "break flour"—meaning the flour obtained after each break; (2) medium-coarse particles called "middlings"; and (3) coarse particles which are carried on to the next pair of rollers for a repetition of the processing.

Each lot of *break flour* is separated from the other portions by sifting through bolting cloth. It is made from the more floury, hence more easily powdered, portion of the endosperm.

Middlings are made up of particles from the less floury portion of endosperm together with some bran. The several streams are purified by subjecting them to air currents to remove bran particles, after which they are ground through a succession of roller-pairs until a flour product of the desired degree of fineness is obtained.

Coarse particles are composed of bran with clinging aleurone cells of endosperm, the more crumbly endosperm not yet crushed into flour, and germ. The proportion of endosperm in coarse particles decreases with each crushing as each new stream of break flour and middlings is sifted out. The bran becomes separated as coarse flakes, the germ as small flakes. This crushing of coarser particles is continued until nearly all of the endosperm and germ are removed. The final product is very largely of coarse bran origin.

Summary. Without entering into further details as to processing procedure, the types of end products obtained from wheat are as follows:

1. Several streams of *break flour*, made very largely from the more floury portion of the wheat's endosperm.

2. Several streams of *middlings flour*, made from coarser endosperm.

3. *Coarser bran* with some adhering cells of aleurone layer of endosperm.

4. *Germ* with clinging bran.

Blending flours. Finally, in assembling the finished flours, various ones of the many streams—break flours, middlings, bran with adhering aleurone, and germ—are selected and blended together. It is evident, then, that the particular streams which are selected for blending must determine the type and quality of the specific flour.

Unrefined and refined flours. As with breakfast cereals discussed in the preceding chapter, two general types of flours are assembled for food uses. These are unrefined or whole-grain flours and refined flours.

Unrefined flours. The two names that are applied to

flours that are obtained by blending *all* of the milling streams are: *whole-wheat flour* and *graham flour*. Furthermore, since these flours contain all of the structural parts of the wheat kernels, they have the highest nutritive value of all flours from this grain.

Ninety-eight per cent flours. Another brand of blended product is assembled which is slightly less than a whole-grain flour. It is blended from streams obtained from about 98 per cent of the whole kernel, lacking only components that are milled from the outside, coarser bran layer. This type of flour, therefore, approximates the whole-wheat variety in nutritional value.

Refined flours. Refined flours are assembled only from those streams which are mainly of endosperm origin—that is, from break flours and middlings. Some of the blends are as follows (see also tabulation on page 69):

Eighty-five per cent extraction flour. Since the endosperm constitutes about 85 per cent of the wheat kernel, it is possible to blend a refined flour from all of the many streams of break flours and middlings in such a manner that the product contains this proportion of the kernel. Such a flour is designated as an 85 per cent extraction flour.

Seventy-two per cent flour. It is the more usual practice, however, to assemble refined flours—hence flours of endosperm origin—that are made up of not more than 72 per cent of the kernel. This is accomplished by excluding some of the middlings and break flour streams.

Patent flours. The so-called patent flours, which are considered especially desirable by the baking trade, are blended from certain streams that come from the more central portions of the endosperm. These flours include less than 72 per cent of the wheat kernel as a whole (p. 69).

Nutritive value of refined flours. Since in the manufacture of refined flours, streams from the bran, germ, and aleurone layers of the kernel are rejected, and since it is in these layers that the minerals and vitamins of the kernel are chiefly

SUMMARY OF COMPONENTS OF UNREFINED AND REFINED FLOURS

Unrefined flours

**Whole-wheat flour
or
Graham flour**

Contains all nutri-
ents of the wheat
kernel

Bran (cellulose) —→
Starch
Proteins
Fats
Minerals
Vitamins

98% flour

All nutrients except
those of outer bran
layer

Less cellulose

Same

Refined flours

Entirely of endo-
sperm origin—bran
with aleurone layer of
endosperm and germ
excluded. Hence
flours are assembled
from break flour and
middlings streams

**85% extraction
flour**

Includes entire endo-
sperm. Assembled
from all streams of
break flours and
middlings

Nutrients present

Starch
Proteins
Minerals
Vitamins } limited

**72% extraction
flour**

Assembled from
break flours and
middlings, except
streams obtained
from outer endo-
sperm

Nutrients present

Starch
Proteins
Minerals
Vitamins } more
limited
than in
85% flour

**Patent
flours**

Assembled from
streams from central
portion of endosperm

Nutrients present

Starch
Proteins
Minerals
Vitamins } similar to
72% flour

concentrated, refined flours are deprived of much of the nutritive value of the original wheat seed. Even so, in respect to such limited portions of minerals and vitamins as do persist in these refined products, it is obvious that an 85 per cent flour (p. 68) is superior to the flour which contains only 72 per cent or less of the wheat kernel.

Types of refined flours. *According to wheat classes from which obtained.* Refined flours are made from hundreds of different varieties of wheats. But, fortunately, all of these numerous wheats fall into only a few classes, the differing characteristics of which are due chiefly to a difference in their protein contents. It follows, then, that flours made from these wheats fall into like classes with like differences as to protein. Moreover, it is interesting to learn that experimentation in cookery laboratories, borne out by the experience of numerous housewives, indicates that flours from each class, owing largely to their peculiar protein content, lend themselves most favorably to the making of specific flour mixtures, such as yeast breads, muffins, or cakes.

This classification of wheats, the flours derived from them, and favored uses for the flours, are summarized in the table on page 71.

Characteristics of these wheats. Durum and spring wheats are sown in the spring and harvested in late summer. Winter wheats are sown in the fall and develop a root system before cold weather begins; they make an early and rapid growth in the spring and are harvested in early summer.

The color of the kernels of red wheats is due to a brownish-red pigment located largely in the bran coats. It may range from light brown to red. White wheats have kernels that are either colorless or faintly yellow because of the presence of flavone or carotinoid pigments.

The texture of the kernels in wheats designated as soft is soft and mealy, while that of the kernels in hard and durum wheats is horny and vitreous.

The three characteristics—(1) growth habit, (2) color of

SUMMARY TABULATION

<i>Wheat classes</i>	<i>Flours made from them</i>		<i>Where wheats are chiefly grown</i>
<p>Durum wheats</p> <p>↓</p> <p>High in protein</p>	Semolina flour	Used for making alimentary pastes, such as macaroni	North and South Dakota, Montana, Minnesota
<p>Hard, red spring wheats</p> <p>↓</p> <p>Hard, red winter wheats</p> <p>↓</p> <p>Rich in protein, varying from approximately 12 to 16%</p>	Hard or strong flours	Used for making yeast breads, quick breads, and pastries	<p>Red spring wheats in: North and South Dakota, Montana, Minnesota</p> <p>Red winter wheats in: Kansas, Nebraska, Oklahoma</p>
<p>Soft, red winter wheats</p> <p>↓</p> <p>White wheats,¹ spring and winter</p> <p>↓</p> <p>Less rich in protein, approximately 8 to 11%</p>	Soft or weak flours	Used for making cakes	<p>Soft, red winter wheats in: Missouri, Illinois, Ohio, Indiana</p> <p>White wheats in: Pacific Northwest, Southern seaboard, Washington, Oregon, Idaho, California, Michigan, New York</p>
		Less rich in protein	

¹ Used also for making breakfast cereals.

kernel, (3) texture of kernel—are related to the protein content of the wheat (see table on p. 71), which is higher in kernels that are darker in color and more horny in texture. There is no hard and fast parallelism in regard to protein content between spring and winter wheats, since, actually, both high and low protein wheats may be found in both classes.

GLUTEN—FRAMEWORK MATERIAL OF FLOUR MIXTURES

Made only from proteins of wheat. In considering the role of flour for the purpose of making flour mixtures—breads, muffins, cakes, and so forth—it is the protein content of flour which is of major importance, since it is from this component that gluten, the framework of flour mixtures, is formed when the flour is moistened. Moreover, the outstanding preference for flours of wheat origin for preparing these mixtures is due to the fact that the ability to form gluten is a unique characteristic of wheat proteins and not possessed by the proteins of any other grain.

A difference in theories concerning origin of gluten. At the present time, there is an increasing tendency on the part of grain chemists toward the belief that protein components of wheat involve just a single, large, protein complex. They believe, further, that when this complex is treated with various reagents—water, salt solution, alcohol, dilute acid—several different fractions become separated, which, although fractions of the same protein, possess individual characteristics. This is admittedly rather vague, but such, briefly, is the present status of the theory which requires much more experimentation for substantiation and understanding.

This is in contrast to the belief of long standing, still accepted by some, that actually the several proteins are really different proteins—not fractions of the same complex—and that they exist already formed, first in the wheat, then in the wheat flour. And since this latter theory is the simpler one, and because it meets our needs by way of explaining the peculiar function of proteins of wheat flour in making flour mixtures, it is the theory favored in this discussion.

Of these proteins, gliadin and glutenin are present in the highest proportions, a fact of great importance, since it is from them that gluten is made; and, as already stressed, it is gluten that forms the framework of flour mixtures.

Gluten formation. When wheat flour is moistened and stirred so that water penetrates among and into the tiny flour particles, a dough is formed. When this dough is kneaded and washed in water, gluten—freed, largely, from other flour components—is obtained as an elastic, coherent mass.

Quantity and quality of gluten varies with different varieties of wheats and flours. The amount of gluten obtained from a given wheat, hence from wheat flour, is directly proportional to the total amount of protein present in it. It follows, therefore, that durum and hard wheat flours must yield more gluten than do soft wheat flours (p. 71). Also, the character or quality of gluten obtained from the two types of flours is different: that made from proteins of hard flours adsorbs (p. 370) more water and is more elastic and cohesive than the gluten made from proteins of soft flours. The reasons for these inherent differences in quality of gluten are not at the present time well understood.

Strong and weak flours and their uses. So it is in terms of quantity and quality of the gluten obtainable from the flour that its strength is largely designated. And these are the factors, too, which influence the particular use in the making of baked products for which a specific flour is best suited (p. 71). Thus, a flour which yields a relatively large amount of gluten, with pronounced elastic and cohesive properties and water-adsorbing power, is considered a *hard* or *strong flour* and is used for making yeast breads in which the leavening action is prolonged. On the other hand, a flour that is capable of yielding a smaller amount of gluten, less elastic and cohesive and less adsorptive as to water, is called a *soft* or *weak flour*, and is better suited for making cakes, pastries, and other products in which leavening action is more rapidly accomplished.

In fact, these two types of flours are commonly referred to

as bread and pastry flours, respectively. However, a flour of intermediate strength, called *all-purpose* or *family flour*, is now available. This flour calls for a skillful blending of wheats of different classes (p. 71) prior to their processing. The characteristics of the gluten obtainable from flour made from such blended wheats are such that the flour can be used to advantage for the making of all types of flour mixtures. Recently, especially milled *cake flours* are also manufactured for their obvious use in cake-making.

Role of gluten in flour mixtures. Gluten may be described as having a mesh-like structure of loosely connected strands, each of which is composed of many protein molecules. The strands are colloidal in dimensions (p. 3), and in a dough mass they form a continuous network which captures innumerable air bubbles as well as gaseous bubbles of other leavening agents (Fig. 7). These strands enmesh

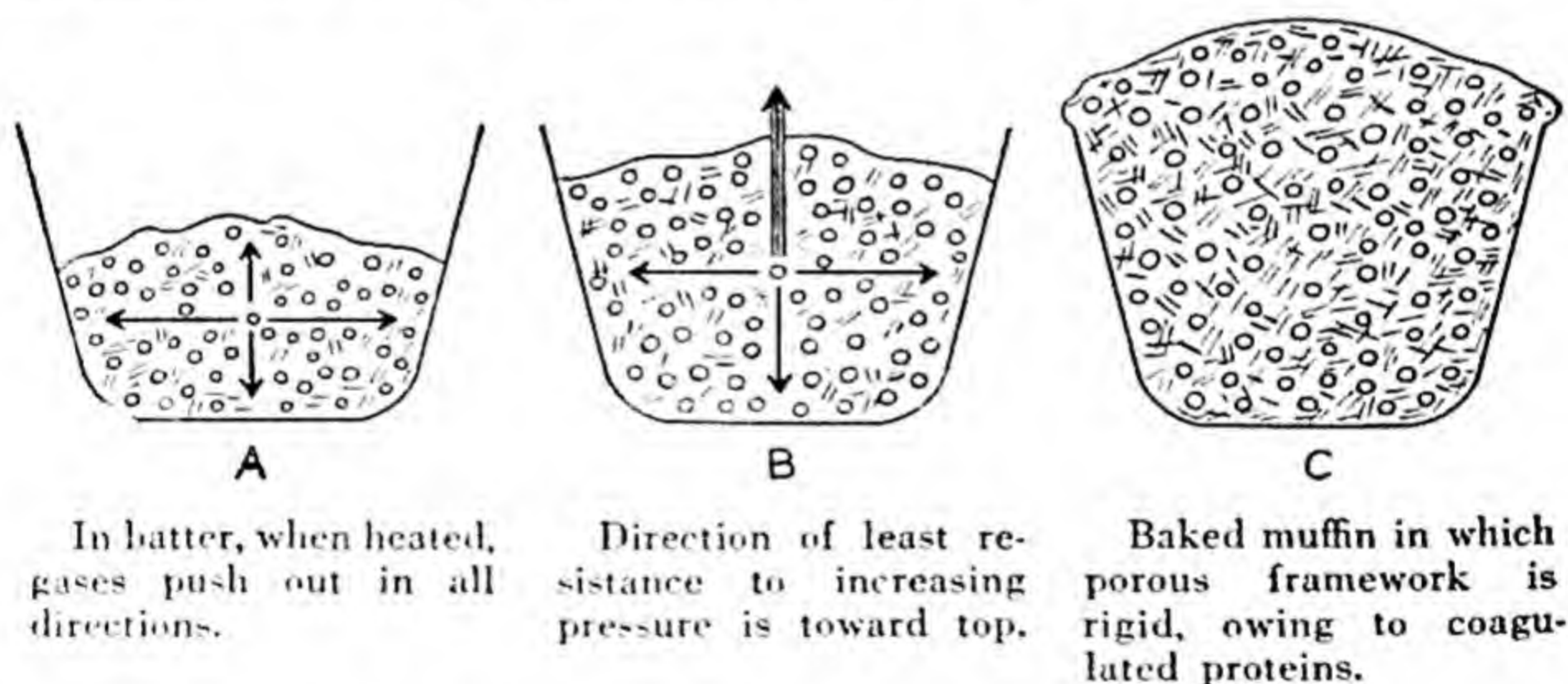


Fig. 7. Representing action of leavening agents in muffin batter.

starch granules and globules of fat; they also hold water adsorbed on their surfaces.

It is this meshwork that constitutes the gluten framework of various flour mixtures. Since gluten is elastic, it stretches as the gases held in the pockets of the mesh expand during the rising of bread dough and during the baking of bread, or muffins, or cake. But, owing to the cohesive property of

gluten, the strands do not break easily, hence some of the expanding gases continue to be held captive within the flour mixtures. Finally, the gluten proteins, as well as other proteins present, become coagulated by heat, at which time the final rigid structure that is characteristic of the specific baked product is obtained.

Exception. In certain flour mixtures, in which there is a relatively large proportion of liquid to flour, the protein strands may become separated to such an extent that a gluten network is not formed. This condition is presumably encountered in the pour-batter type of flour mixtures (p. 93).

Gluten manipulation and its effect on properties. The mechanical treatment to which gluten is subjected during the mixing process is said to "develop" it, that is, it brings out the elastic and cohesive properties of the gluten until the right consistency is imparted to the framework.

A caution. But an intelligent and cautious mixing treatment is nonetheless important, since it is possible to continue this development to such an extent that the gluten strands are made too strong, and toughness results in the finished product.

Effect of other components. The development of gluten is influenced not only by the inherent character of the gluten itself, but also by ingredients which accompany it in the dough mass. These effects vary and will be discussed more specifically with respect to individual types of flour mixtures—breads, cakes, and so forth; but some consideration seems appropriate at this time.

The leavening agent (p. 77), whether it is air, carbon dioxide, or steam, permeates the gluten network and makes it porous and light.

Fats, being insoluble in water, tend to spread on surfaces of water in contact with gluten strands. Hence, the presence of this film of fat prevents gluten strands from adhering too firmly to one another in a continuous mass. This has a tendency to increase the tenderness of the finished baked product.

A flavorful fat will, of course, add to the palatability of the product.

Sugar is used in flour mixtures for flavor and to enhance the browning of crusts as the sugar at the surface of the mixture caramelizes during baking. The presence of sugar also affects the tenderness quality of the product, since it exerts a peptizing action (p. 367) on the proteins, thereby weakening somewhat the gluten framework.

Caution. But it should be emphasized that in the presence of an excess of sugar this weakening may become so pronounced that some gas bubbles break through gluten walls to join one another. A gluten framework of larger mesh thus becomes established which results in a finished baked product coarser in grain (p. 111).

Egg components impart color and flavor to a baked product. Also egg proteins, upon coagulation, contribute to the framework material of the flour mixture. Beaten egg white, when used, adds air bubbles to the mixture.

Salt is used chiefly for flavor, although under some circumstances its presence may affect the strength of the gluten framework.

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CHAPTER VII

LEAVENING AGENTS

Terms. *Leavening agents* are gaseous substances which become incorporated into a food mixture for the purpose of making it porous and light. The resulting food mass is called a *leavened product*, in contrast to products of the unleavened variety, typified by unleavened bread, which are nonporous.

Use of terms is limited. Were the above definitions to be accepted without reservation, it would follow that beaten egg whites, cream foams, a whipped gelatin, a puffy omelet, and a soufflé should be included among leavened products, since they are “lightened” by incorporated air. In actual fact, however, it is customary to restrict the use of the term “leavened” to flour mixtures—raised bread, biscuits, cakes, and their like—which have been rendered porous and light, and to designate as “leavening agents” either the gaseous substances immediately responsible for the leavening, or the materials concerned with the production of these gases.

Of cookery importance. Obviously, leavening agents play an important role in cookery since, through their functioning, a large variety of baked flour mixtures can be made which are attractive in appearance and, in all respects, more palatable than unleavened, hence more compact, products.

Three leavening agents. There are three leavening agents: *air*, *steam*, and *carbon dioxide*. *Air* becomes incorporated with a flour mixture by various mixing technics such as folding, creaming, and beating, also by blending into the mixture an egg white foam. *Steam* is generated within the

food mass as the water component vaporizes during baking. The third leavening agent—*carbon dioxide*—is made within the food mass either from reactions catalyzed by enzymes provided in yeast (p. 100), or from reactions between certain compounds that are purposely introduced into the flour mixture for this purpose. Examples of the latter reactions are the making of carbon dioxide from contacts between lactic acid of sour milk and bicarbonate of soda, or between components of a baking powder (p. 83).

Leavening usually due to all three agents. Some flour mixtures, like popovers, depend for their leavening almost entirely upon steam generated within the batter during baking, while others, such as pastries, depend upon both steam and air for this purpose. But the fact remains that most flour mixtures owe their lightness to the expansion of all three leavening agents, with one of them usually playing a dominant role.

Action of leavening agents. The mode of action of the three leavening agents is the same. They become entrapped as innumerable small gaseous bubbles within the structural framework of the flour mixture where, during the baking process, the heat of the oven causes them to expand, hence to push out against the mixture in all directions (Fig. 7A). But, since the dough mass is customarily confined at bottom and sides in some sort of a baking dish, the direction of least resistance for gas expansion is necessarily toward the top. This accounts for the continuous “lifting” of the flour mixture involved (Fig. 7B) until such a temperature is reached as to render the framework rigid owing to the coagulation of proteins of which it is largely composed (Fig. 7C).

This rigidity of framework should become established at just the right degree of lightness of the food mass as a whole, owing to just the right degree of expansion of the entrapped gases. Therefore, careful adjustment is necessary with respect to baking temperature and time, both for each specific

type of flour mixture and for each dominant leavening agent concerned.

Examples: 1. Popovers must be put into a very hot oven, since their leavening depends largely upon the rapid vaporization of water which permeates the batter. Pastries, likewise, must be put into a hot oven, since their aeration and the desired layering effect depend both upon the rapid expansion of entrapped air and upon the rapid vaporization of water.

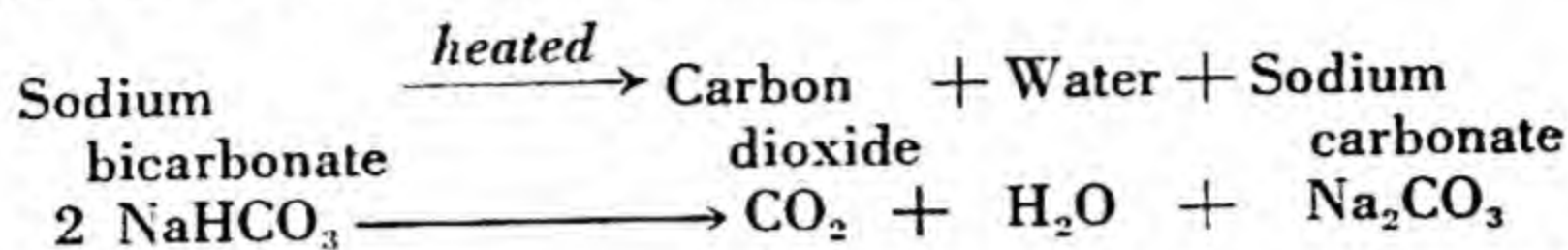
2. In the baking of a cake, however, in which the dominant leavening agent is carbon dioxide, this gas must first be made—usually from components of baking powder. Therefore, the oven temperature should be more moderate in order to give time for the continuance of the chemical action, commonly initiated during the mixing, whereby this leavening agent is generated.

How prevent collapse of baked product. Before removing any leavened flour mixture from the oven, the heat treatment must have been sufficient to assure the maintenance of the rigidity of its framework. This is necessary, since all gaseous bubbles that remain entrapped will contract during cooling, thereby withdrawing gradually the support of their pressure. To offset this effect, a short baking period is usually advised beyond the time when the complete expansion desired has taken place.

Obtaining carbon dioxide for leavening. Obtaining carbon dioxide through the agency of enzymes provided in yeasts will be considered under the study of yeast breads (p. 93). Therefore, the present discussion will be confined to methods employed for making this gas from reactions involving baking soda (sodium bicarbonate) either with acids or with substances present in baking powders.

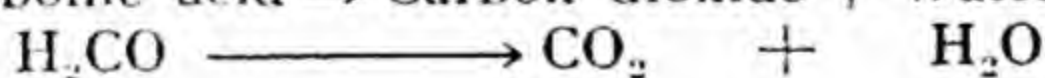
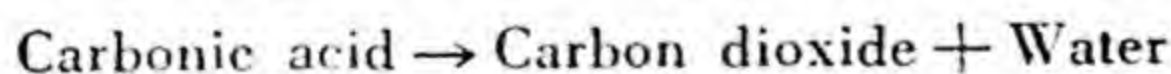
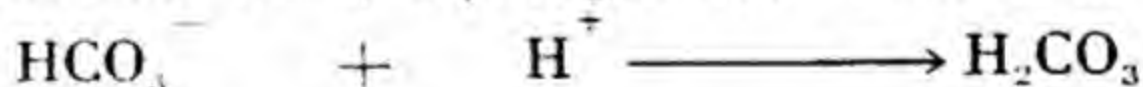
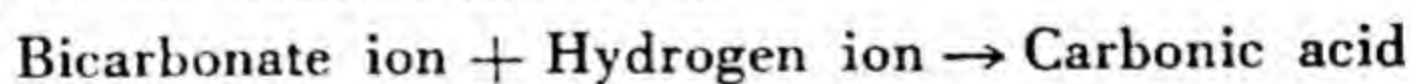
Why baking soda must react with another substance. When sodium bicarbonate is heated by itself—that is, without the presence of a reacting partner substance—it decomposes to make the products water, carbon dioxide, and sodium carbonate. Therefore, should this reagent be used *alone* in the flour mixture as the source of carbon dioxide as aerating agent,

sodium carbonate (washing soda) would remain as a solid, unpalatable residue in the finished product.



This being the case, and in order to obtain along with the carbon dioxide a residue which is palatable, it is necessary to use with the baking soda either an acid such as lactic acid of sour milk, or an acid-reacting salt such as those present in baking powder mixtures.

Immediate source of carbon dioxide. But whether the reacting partner substance for baking soda is an acid or an acid-reacting salt, the reactions which lead directly to the making of carbon dioxide are the same. Accordingly, when in water, bicarbonate ions (HCO_3^-) from baking soda¹ and hydrogen ions (H^+)—obtainable either directly from the acid² or acid salt,³ or indirectly from the acid-reacting salt⁴—combine to make carbonic acid, which, being unstable, decomposes to give carbon dioxide and water. The latter reaction takes place slowly at ordinary temperatures but more rapidly in the heat of the oven.



Equations which represent only the beginning substances and final products, ignoring any intermediate reactions, are given in a later study (p. 85).

¹ Sodium bicarbonate \rightarrow Sodium ions + Bicarbonate ions

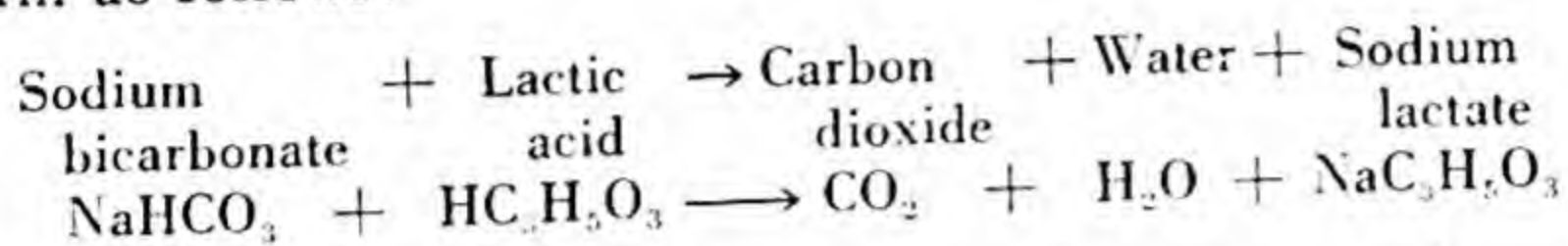
² Lactic acid \rightarrow Hydrogen ions + Lactate ions

³ Potassium acid tartrate \rightarrow Hydrogen ions + Potassium ions + Tartrate ions

⁴ Sodium aluminum sulfate + Water \rightarrow Sulfuric acid + Sodium sulfate + Aluminum hydroxide
 \downarrow
 Hydrogen ions + Sulfate ions

CARBON DIOXIDE FROM BAKING SODA WITH ACIDS

Reactions concerned. In the aeration of flour mixtures with sour milk or molasses as ingredients, the lactic acid of sour milk or the several acids of molasses react with sodium bicarbonate to make carbonic acid, which decomposes in the manner just presented to produce the desired carbon dioxide. These two reactions are represented in condensed form as follows:



Directions for use of baking soda. Formerly. In many old recipes one finds that directions call for the mixing of baking soda with the sour milk or molasses before adding it to the dry ingredients of the flour mixture. But when this procedure is followed, since rapid reaction begins at once, a large proportion of carbon dioxide is lost into the air. No doubt this method of mixing was advocated in early recipes because, formerly, baking soda was not as finely pulverized as it is today. Hence, it was necessary to mix it directly with water—the dispersing liquid of both milk and molasses—in order to effect its complete solution.

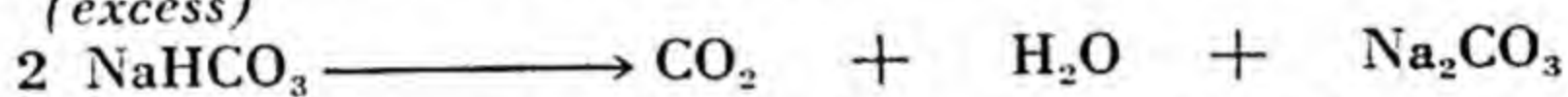
Modern method. But the more finely powdered baking soda of today should be mixed and sifted with the flour and other dry ingredients before this dry mixture is brought into contact with acid-containing liquid ingredients. When this procedure is followed, less carbon dioxide is lost and a greater portion of this gas becomes at once entrapped within the framework of the flour mixture, where it begins to exert a leavening action even during the mixing procedure.

Proportion of baking soda advised. Since different lots of sour milk and molasses vary in quantities of acids present, it is impossible in the home to ascertain the quantities of baking soda to use in order to neutralize the acid components exactly. Therefore, an *average* amount is rec-

ommended of $\frac{1}{2}$ teaspoonful of soda for each cupful of sour milk or sour buttermilk, and from $\frac{1}{2}$ to $\frac{3}{4}$ teaspoonful for each cupful of molasses.

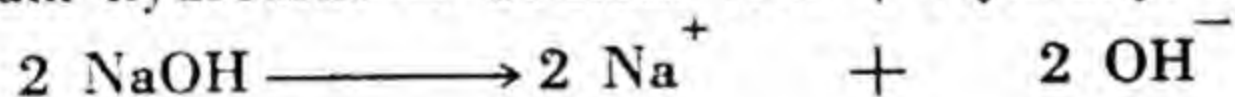
Excess of baking soda. Should the above proportions provide an excess of baking soda over that required to neutralize the acid or acids present, this excess will be decomposed by heat during the baking of the flour mixture, according to the reaction discussed previously (p. 80), and sodium carbonate will be made. This salt is responsible for the production of an alkaline reaction in the moist medium provided by the flour mixture, owing to its hydrolysis and the consequent appearance in solution of hydroxyl ions. Reactions concerned are represented as follows:

Sodium bicarbonate \rightarrow Carbon dioxide + Water + Sodium carbonate
(*excess*)



Sodium carbonate + Water \rightarrow Sodium hydroxide + Carbonic acid
 $\text{Na}_2\text{CO}_3 + 2 \text{ HOH} \longrightarrow 2 \text{ NaOH} + \text{H}_2\text{CO}_3$

Sodium hydroxide \rightarrow Sodium ions + Hydroxyl ions



Undesirable effects. If the excess of sodium bicarbonate is present in appreciable amounts, the resulting alkalinity will be sufficient to affect adversely the taste of the baked product. It may, also, cause the flavone pigments of the flour to turn a brownish color; which accounts, at least in part, for the brownish-yellow specks that appear in the crumb of light-colored baked products in which an excess of sodium bicarbonate has been introduced. Moreover, the alkaline reaction results in an undue destruction, during baking, of any thiamine that may be present in the batter or dough.

Occasionally produces desired effects. But in flour mixtures that contain molasses or chocolate, a limited alkaline reaction resulting from a small excess of baking soda often produces effects that many people like: namely, a darkening

of molasses and chocolate pigments to a rich brown. Another characteristic effect that is produced in a very dark chocolate cake is the exceedingly tender crumb which is the result of a peptizing action (p. 367) of the alkali upon proteins of the flour.

It follows that, for those who enjoy these qualities in the finished product, recipes frequently list larger amounts of baking soda than are required just to neutralize the acid components present. *A caution.* But, even though the darker colors and tenderness-of-crumb may be desired by many people, an undue excess of baking soda must be guarded against, because of a contributing flavor that no one enjoys.

BAKING POWDERS AS SOURCE OF CARBON DIOXIDE

The baking powder of earlier days and those of today. In days before the use of commercial baking powders became prevalent, the housewife kept on hand in separate packages supplies of cream of tartar and bicarbonate of soda—or saleratus, as it was usually named—and mixed them as needed. Directions called for a very careful powdering of each of these salts with a thin knife edge on the hard surface of the mixing board, then a painstaking spoon-measuring of the two before mixing as thoroughly as possible. Obviously, according to this procedure, the probability of obtaining the just-right proportions of baking powder components without excess of either was entirely a matter of chance, and rarely, if ever, achieved.

This uncertainty has been removed through the use of commercial baking powders in which contributing substances are weighed out very carefully in the manufacturing process and mixed thoroughly in the exact proportions in which they react. Also, baking powder mixtures are now manufactured other than those that contain cream of tartar.

Official definition. A baking powder is defined by the United States Department of Agriculture as: “. . . the leavening agent produced by the mixing of an acid-reacting

material and sodium bicarbonate with or without starch or flour. It yields not less than 12 per cent of available carbon dioxide. The acid-reacting materials in baking powder are: (1) tartaric acid or its acid salts, (2) acid salts of phosphoric acid, (3) compounds of aluminum, or (4) any combination in substantial proportions of the foregoing.”⁵

Although this definition does list starch as an optional ingredient, actually it is always a baking powder component, where it serves two functions. (1) It acts as a diluent, and as such, is incorporated in the baking powder mixture in such a proportion as to standardize the yield of carbon dioxide at slightly above the 12 per cent level. (2) In addition, the starch functions as a drying agent to provide unfavorable conditions (absence of moisture) for interaction between the active components of the baking powder until ready for use; a precaution which prevents its deterioration between the time of its manufacture and its use by the consumer in the home.

Reaction from which carbon dioxide is made. As has been stated previously (p. 80), in a liquid medium involving water (usually milk), the acid or the acid-reacting salt (directly or indirectly) provides hydrogen ions (H^+) and the sodium bicarbonate provides the bicarbonate ions (HCO_3^-). These two ions combine to make carbonic acid, which decomposes readily to water and carbon dioxide (p. 80).

Classification. These several kinds of baking powders are classified as tartrate, phosphate, sulfate, and sulfate-phosphate powders. Components of these baking powders are:

Tartrate powders

Sodium bicarbonate
Potassium hydrogen tartrate
(cream of tartar)
and
Tartaric acid

Phosphate powders

Sodium bicarbonate
Calcium dihydrogen phosphate

⁵ United States Department of Agriculture, Food, Drug, and Insecticide Administration, S. R. A., F. D. 2, Revised 4, 1933, p. 20.

Sulfate powders

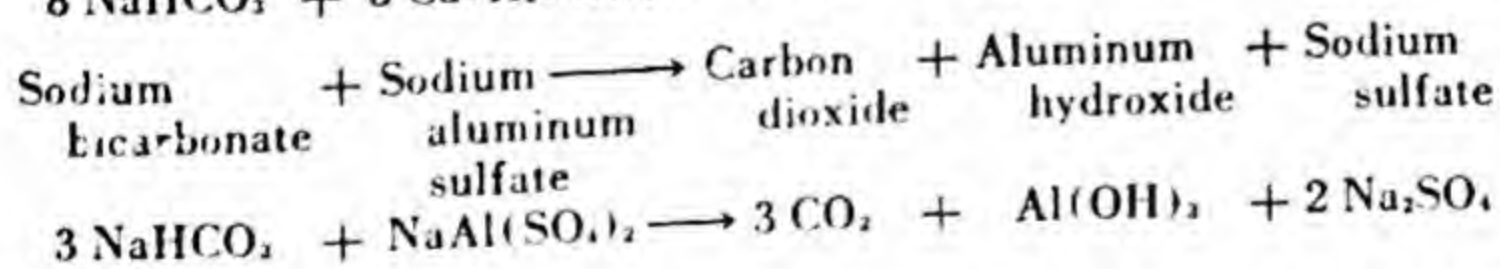
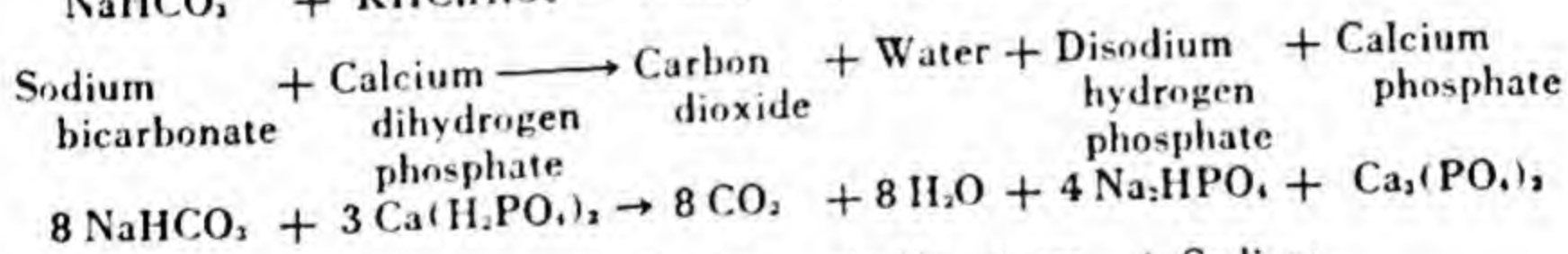
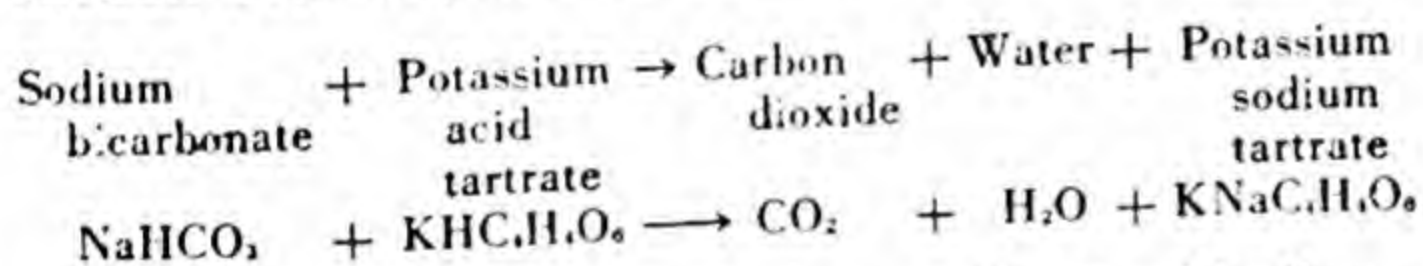
Sodium bicarbonate
Sodium aluminum sulfate

Sulfate-phosphate powders

Sodium bicarbonate
Sodium aluminum sulfate
and
Calcium dihydrogen phosphate

Directions for using and reactions concerned. For the introduction of baking powder into a flour mixture, the same procedure should be observed as in the use of baking soda with acids (p. 81). The baking powder, together with other dry ingredients, should be incorporated with the flour and sifted before the introduction of the liquid components.

Equations for inclusive reactions, meaning equations which mention only the beginning active ingredients of the baking powders and the end products, without indicating intermediate steps whereby carbonic acid is made and decomposes to make carbon dioxide, are as follows:



Advantages and disadvantages of these baking powders. *Ideal leavening conditions.* Before entering into relative merits of these baking powders it would be well to consider what one should expect from ideal leavening conditions. Accordingly: (1) The flour mixture should preferably become impregnated to some extent with carbon dioxide during the mixing. (2) In the oven, reactions from which carbon dioxide is made should take place with increasing speed as the flour mixture attains successively higher temper-

atures, until a temperature level is reached which causes the framework of the baked product to become rigid. (3) Just enough carbon dioxide should be made, hence just enough baking powder should be introduced into the flour mixture, to accomplish continuous leavening up to this point. (4) Finally, the residue remaining in the finished product should be unobjectionable.

Efficiency of these baking powders. But as to items (3) and (4) above, the facts are that all types of baking powders yield approximately the same percentage of carbon dioxide; and, when reactions are complete, the salt residues that remain in the biscuits, cakes, and so forth, are palatable and harmless. So that, from these two standpoints, no one baking powder has any advantage over the others.

Thus it is, then, that the significant difference among baking powders is in respect to their ability to carry on reactions for making carbon dioxide within the flour mixture, both at ordinary temperatures during the mixing period and at high temperatures during baking. The following is a brief discussion of the extent to which the several baking powders meet these conditions.

Tartrate and phosphate baking powders (p. 84). As for tartrate baking powders, reactions involving sodium bicarbonate both with potassium acid tartrate (cream of tartar) and tartaric acid begin to take place immediately upon contact with water, which is chief among the liquid components. Therefore, reactions proceed quite speedily at temperatures that prevail during the mixing period. The same is true of reactions involving sodium bicarbonate and the phosphate salts of phosphate baking powders.

The result is that during the mixing period considerable carbon dioxide is lost from the flour mixture, and is therefore made unavailable for leavening action. Reactions do continue at the higher temperatures attained in the oven, but, because of the early loss of carbon dioxide, an introduction of a larger proportion of tartrate and phosphate baking pow-

ders is necessary than of the sulfate variety in order to accomplish the same degree of aeration.

Sulfate baking powder (p. 85). On the other hand, sodium bicarbonate and sodium aluminum sulfate do not even begin appreciable reaction until the flour mixture becomes hot. For this reason, there is always a possibility that too little carbon dioxide may be made to produce adequate leavening action before the protein framework of the baked product becomes set. It is not surprising, therefore, that sulfate baking powders are not extensively used.

Sulfate-phosphate baking powders (p. 85). These are called combination or double-acting baking powders, since they are designed to meet both leavening conditions: (1) leavening of the flour mixture during mixing procedure at ordinary temperatures, due to the making of carbon dioxide from reactions involving sodium bicarbonate and acid-phosphate salt; and (2) leavening during baking, due to the making of this gas at oven temperatures from reactions involving baking soda and sodium aluminum sulfate.

Amounts of baking powders advised. As said previously, because of their considerable reaction at ordinary temperatures, it is customary to use slightly larger amounts of tartrate and phosphate powders than of the sulfate or sulfate-phosphate types. Hence, in general, the proportions recommended are approximately $1\frac{1}{2}$ teaspoonfuls of the first two powders to 1 cupful of flour, but only 1 teaspoonful of the sulfate and sulfate-phosphate powders. In actual practice, however, the exact proportion of any baking powder that one should use with any given flour mixture should be influenced by the character of other ingredients and by the method of mixing. For example:

A smaller proportion of baking powder should be used when part of the leavening of the flour mixture is provided for by the incorporation of considerable air, owing either to the introduction of beaten egg whites or to extraordinary mixing. Also, less baking powder is required when part of the aeration

of the flour mixture is due to the formation of considerable steam throughout its mass when heated in the oven.

Variety of baking powder versus extent of mixing and baking temperatures. When tartrate and phosphate baking powders are used, because of the immediate making of carbon dioxide, the mixture should be assembled as speedily as is consistent with thoroughness and the flour mixture put into the oven without undue delay.

But, because of the delayed making of carbon dioxide from the sulfate and sulfate-phosphate types of baking powders, flour mixtures in which they are used can be stirred for a longer time without danger of excessive loss of gaseous leavening agent before the product is placed in the oven. Also, because of this delayed action, a slightly lower baking temperature is sometimes recommended for any flour mixture which contains either of these two types of powders. This will allow for full making of carbon dioxide, hence for full leavening action in the oven, before the structural protein framework becomes so rigid as to resist further gaseous pressure.

Baking powder augmented by baking soda when sour milk is substituted for sweet milk. The housewife meets this situation whenever she has on hand a supply of sour milk which she wishes to make use of in a flour mixture, the recipe for which calls for sweet milk and baking powder. The altering of the recipe so that baking soda can be substituted for part of the baking powder necessitates the following considerations:

1. Such a quantity of baking soda must be used as is necessary to neutralize the lactic acid of the sour milk ($\frac{1}{2}$ teaspoonful for each cupful); at the same time, a partial leavening of the flour mixture is provided for through the agency of the carbon dioxide that is made as one product of the reactions concerned.

2. The rest of the leavening of the flour mixture must be accounted for by baking powder—the amount specified in

the original recipe, reduced by the baking powder equivalent of the baking soda used with the acid, or a reduction of:

- 1 teaspoonful of baking powder for $\frac{1}{4}$ teaspoonful of baking soda.
- 2 teaspoonfuls of baking powder for $\frac{1}{2}$ teaspoonful of baking soda.

The reason for this relationship is that all baking powder formulas call for the inclusion of approximately one-fourth in bulk of baking soda. An example suggestive of such a recipe alteration is as follows:

Should the original recipe with sweet milk call for	The altered recipe, provided 1 cupful of sour milk is used, should include
↓	↓
4 teaspoonfuls of baking powder	$\frac{1}{2}$ teaspoonful of baking soda 2 teaspoonfuls of baking powder

This rough quantitative relationship between baking soda and baking powder is a convenient guide to follow as occasion demands.

Brown specks in flour mixtures containing baking powder. Very frequently, baked products which are leavened by carbon dioxide made through the agency of baking soda and an acid-reacting salt, as components of the baking powder used, will show the presence of tiny yellow or brownish specks. Several explanations are given for this troublesome phenomenon.

It is certain that, when starch is only slightly moist, in either an alkaline or acid environment, and at such high temperatures as can be easily attained by flour mixtures in the oven, it can undergo a change, called dextrinization, during which a brownish material is made.⁶

It would follow, then, that within a flour mixture, whenever bits of either unreacted baking soda or an acid-reacting salt

⁶ Rask, O. S., "An introductory story of baking powders," *Journal of Chemical Education*, Vol. 9 (1932), pp. 1340-1357.

Newton, H. M., and Williard, A. C., "The occurrence of dark specks in baking powder products," *Canadian Chemistry and Metallurgy*, Vol. 18 (1934), pp. 138-139.

become isolated here and there in contact with particles of starch, dextrinization of these particles can be expected to occur as moisture decreases considerably in the final baking stages.

This effect is frequently encountered in mixtures which contain little liquid, such as baking powder biscuits, or which require very little mixing, such as muffins, both of which are baked at high temperatures. Under these conditions it is not surprising that the formation of brown specks is most marked at crust areas where moisture is least and temperature of the biscuits or muffins is highest.

Another accounting for the appearance of a sprinkling of brown spots as to flour mixtures—and an explanation given previously (p. 82)—concerns the flavone pigments of flours which turn a brownish color when in an alkaline environment, such as is obtained wherever bits of moist unreacted baking soda are located.

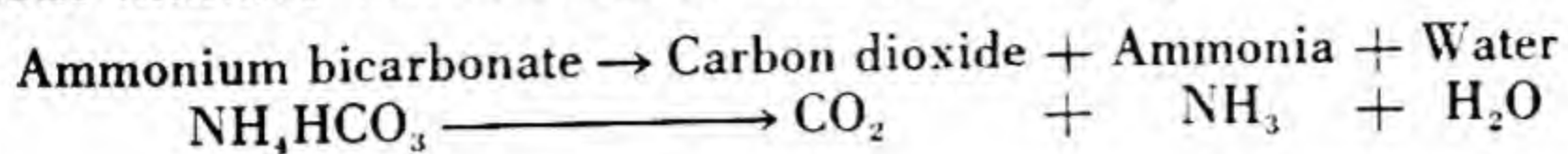
Care of baking powders. It has been stressed throughout the discussion of baking powders that reactions between the active components take place only in a moist medium. It follows therefore, that, during storage, containers holding baking powders must be kept tightly closed in order to prevent air, carrying moisture, from gaining access to the baking powder mixture. For like reason, the container should always be re-covered immediately after measurements of baking powder are made. If these precautions are observed, deterioration of the powders is prevented over a considerable length of time.

BAKING AMMONIA OR AMMONIUM BICARBONATE

This reagent, as a source of gaseous substances for leavening purposes, is used more extensively in commercial and institutional baking than in households. Its use is chiefly limited to the making of thin-baked products such as cookies from which the ammonia gas can escape readily.

When baking ammonia is heated, it decomposes to make carbon dioxide, ammonia, and water. Therefore, when a

flour mixture which contains this aerating agent is subjected



to the heat of the oven, leavening is due to all three gases.

The only residues that remain in the cooled baked product are any gaseous carbon dioxide and ammonia that are still imprisoned, and unreacted ammonium bicarbonate, the steam having condensed to water.

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CHAPTER VIII

FLOUR MIXTURES I—YEAST BREADS— QUICK BREADS

Flour mixtures. Flour mixtures is a term that applies inclusively to the several groups of baked products which have *flour and water* (the latter alone or in milk) as the common and basic ingredients. The characteristics which are peculiar to baked products of each group are determined by several factors: the kinds and amounts of ingredients other than flour and water—sugar, fat, eggs, flavoring—that are used; the manner in which these ingredients are blended to make the mixture; and, finally, the manner in which the flour mixture is baked.

Classification. One method. According to one method of classifying flour mixtures, they fall into two groups termed *yeast breads* and *quick breads*, the basis for the classification depending upon the speed with which leavening action in the mixture is accomplished. If the leavening takes place *slowly*, by means of the expansion of carbon dioxide gas that is made through reactions catalyzed by yeast enzymes, the mixture is a *yeast bread*. But if the leavening takes place with *comparative rapidity*, the flour mixture is a *quick bread*; in these latter mixtures leavening is accomplished: (1) by expansion of steam and air entrapped in the mixture, and (2) by expansion of carbon dioxide produced through chemical reaction either between components of baking powder or between baking soda and an acid or an acid-reacting salt.

Classification followed in this text. The one difficulty with the above classification is that numerous flour mix-

Yeast breads—include bread, rolls, coffee cakes.

Cakes and cookies—include quickly leavened baked products that are sweet and are suitable for use as desserts.

A third basis for classification. A method that is frequently found convenient for classifying flour mixtures groups them, according to the consistency of the raw mixture, into *batters* and *doughs*, and it stipulates the *approximate* proportion of liquid ingredient to flour used in making them. This classification scheme together with examples for each sub-group is as follows:

Pour batters—1 part liquid to 1 part flour } griddle cakes
popovers

Doughs

Stiff doughs—1 part liquid to 4 or more parts flour { cookies
pastries

Yeast breads, whether in homes or displayed in markets, appear in various sizes and shapes and with various flavors;

they range all the way from the simple, traditional loaf of bread to the fancy coffee cake or even more elaborate tea ring filled with fruits and nuts and topped with a sugar frosting. But no matter how simple or how elaborate the yeast bread products may be, they play the same role—namely, as breads—in meal planning. Furthermore, essential features in their making are the same: (1) they have certain ingredients in common; (2) there are common steps in procedure in their making, from the initial step of mixing the ingredients into a dough, to be followed by a kneading of the dough; and (3) they have similar fermentation periods before their final baking.

It is a study of the role of each ingredient and the function of each step in the procedure for making the yeast bread with which the following discussions are concerned.

The ingredients. Flour. Flours that are best suited for use in making yeast breads are those which are milled from the hard red spring and hard red winter wheats (p. 71). These flours are sold either as bread flour or all-purpose flour, depending upon the particular varieties of these two classes of wheats that are selected for milling and upon the particular mill streams (p. 67) that are blended to make them.

High in yield of gluten of good quality. The distinguishing feature of these flours as compared to other flours, such as pastry flours, is that they are *strong*. This means that they have a relatively high content of the proteins gliadin and glutenin, which, when moistened as in the bread-making process, yield a relatively large amount of gluten; and gluten plays a more conspicuous role in the making of yeast breads than in any other type of flour mixture. Also the gluten obtained from strong flours is of *excellent quality* for bread-making, in that, as it is developed (p. 75) upon kneading, its pronounced elastic and cohesive properties enable it to stretch without breaking during fermentation, as carbon dioxide, captured within innumerable pockets in the gluten mesh

throughout the dough, expands to produce the "lightening" effect.

Water. The function of water in bread-making is first of all to bring about the formation of gluten from the two wheat proteins glutenin and gliadin. In fulfilling this function a considerable quantity of the water used becomes adsorbed (p. 370), both at surfaces of the protein molecule aggregates that make up the gluten and at surface areas of starch granules of the flour that are intimately associated with the gluten. The remainder of the water—that is, the portion that does not become thus adsorbed—acts as a solvent for sugar and salt, and as a dispersing medium for fat and for yeast cells with their contained enzymes. In this manner all water-dispersed substances, whether in true or colloidal solution or in suspension, become distributed more or less uniformly in every part of the dough mixture and thereby come into contact with the gluten framework. **Milk**, with its more than 85 per cent water, may be used in bread-making instead of just water, and the components of milk, other than water, not only contribute flavor to the bread but they increase its food value, especially with respect to the element calcium, and to proteins, vitamin A, and riboflavin. Also bread made with milk is thought to keep fresh longer than that made with just water.

Yeast. Yeast is used in bread-making in order to produce the leavening agent carbon dioxide. This gaseous substance is a product of life activities of tiny yeast plants that are multiplied whenever yeast cells are surrounded by a suitable environment of moisture, warmth, and nutrients, such as is obtained in properly attended bread dough.

The type of yeast commonly used for making bread is called bakers' yeast which is assembled in various ways: as dry cakes, as compressed cakes, or in a finely crumbled form. In the making of *dry cakes*, the myriads of infinitesimal yeast plants are mixed with some material, like moist corn meal, after which the mixture is pressed into cakes and thoroughly dried. In this condition yeast can be kept for several months

without deteriorating; but before being used the cakes must be well moistened in order to bring the yeast cells, including their contained enzymes, into an active state. In *compressed cakes*, yeast plants are mixed with a starchy material, but the mixture is dried only sufficiently to render the mass of such a consistency that it can be pressed into cakes. The cakes are then wrapped in foil in order to retain moisture and exclude air. Recently, a *crumbled yeast* of intermediate degree of dryness has become available. This yeast comes in packages, each carrying a date which indicates the time within which the product should be used. In speed of action, crumbled yeast resembles that of the familiar compressed yeast. These two types of moist yeast—compressed and crumbled—should be of an even, creamy color and should have a pleasant, aromatic odor. All yeasts, with contained enzymes, are in a more or less active state; therefore in order to prevent deterioration they should be kept in a refrigerator until used. In the case of compressed yeast the period should not exceed 3 or 4 days.

Sugar. Although sugar is not an essential ingredient of yeast bread, its presence is desirable, since it provides an *immediate* and *adequate* supply of fermentable sugar in the dough mass so that reactions toward the making of carbon dioxide, catalyzed by enzymes of yeast cells, can begin as soon as the dough is mixed. If sugar is not an added ingredient, the fermentation reaction is considerably delayed, since it must await *first* the slow making of maltose from the starch of flour, the reaction being catalyzed by the enzyme diastase (p. 100), and *second* the conversion of maltose into glucose from which the carbon dioxide is produced. Equations for the reactions concerned are given on page 100. Sugar is desirable, also, because of the flavor it contributes and because, due to its caramelization on the surface of the bread during baking, an attractive brown color is imparted to the crust of the finished loaf.

Fat. Fat is an optional ingredient of yeast breads inas-

much as very good bread can be made without it. The use of fat has the effect of producing a more tender loaf and one with a browner crust with more of a "bloom" on it. The tenderizing action is attributed to the fact that fat, becoming distributed throughout the dough mass during the mixing and kneading processes and being insoluble in water, forms thin films over the water that is held adsorbed at surfaces of the numerous gluten strands. The strands are thereby prevented from adhering to each other to form a too-rigid mass, a condition which would result in a tough product in the finished loaf.

Salt. Salt must always be used in bread; without it much of the flavor would be lacking. Also, bread that is made without salt is generally inferior in quality. The action of salt as it affects gluten framework is not clear, but it is noticeable that without this component the dough becomes sticky upon being kneaded. This would indicate that the presence of salt has a desirable firming effect on gluten strands.

The procedure in making yeast breads. *Mixing.* The ingredients for yeast bread should first be assembled and then mixed to make a dough. Several methods for mixing are recommended, but any method of personal preference can be used, so long as it intimately mixes all ingredients to make a soft dough of such consistency that it can be removed to a board for kneading. During the mixing process, flour particles with their contained proteins are wet with water so intimately that gluten is formed and the dough structure started.

Kneading. This is the step in the bread-making procedure in which the dough is worked, either on a board by hand or in a machine, until it becomes a smooth, even mass. While this is being accomplished, fermentation reactions begin to take place and bubbles of carbon dioxide are formed which, as kneading is continued, can be seen under dough surfaces.

Gluten development. But the main object of kneading is to *develop* the gluten. Gluten has been described (p. 74)

as having a mesh-like structure of loosely connected strands, each strand being composed of many protein molecules. When first formed in the dough, these strands may be thought of as being arranged in the mesh structure in a more or less haphazard and disorderly fashion, and only very loosely connected one with the other. Kneading is said to: (1) rearrange these strands into a mesh, more orderly in pattern, and (2) to enhance the elastic and cohesive qualities of the gluten, as the result of which the whole structure becomes firmer and, at the same time, more elastic. Also, while kneading, more and more water becomes adsorbed on surfaces of gluten strands, as well as on surfaces of starch granules which, during the mixing and kneading, have become embedded in the gluten.

These changes which take place in gluten structure in the course of kneading constitute what is called gluten development, and they are made apparent as the dough, during kneading, becomes less sticky, more elastic, more firm and well rounded, and finally takes on a smooth, dull, satiny appearance.

It is in this manner that gluten is brought to the just-right condition of elasticity and cohesiveness so that, as the dough becomes impregnated with carbon dioxide, the strands can be stretched and drawn out into thin filaments, which in their fine criss-crossing network enclose this gas in numberless tiny pockets. Moreover, these filaments do not break to release this gas either as it continues to be made all during the fermentation period or, later, as the gas expands in every part of the dough during baking. As a result, the finished product is porous in character with small, evenly distributed, and thin-walled cells.

Over-kneading to be avoided. If kneading of the dough is continued much beyond the point at which the characteristics of gluten development, as presented above, become noticeable, the dough will become softer and more moist in feeling, and will tend to stick to the board. These are signs

of *over-kneading* and indicate, possibly, that gluten strands are being stretched so excessively thin that the mesh-like structure is beginning to give way. It is true, therefore, contrary to the belief of many, that bread dough can be kneaded too much; consequently, caution should be observed to avoid this happening.

Dough fermentation. The third step in making bread, the *dough fermentation period*, is that in which the kneaded dough is set aside in a warm place in order to give time and provide favorable conditions for the continuous making of carbon dioxide. This gas is the predominating leavening agent in yeast breads, the relatively small amounts of moisture in the dough and of air incorporated during mixing and kneading having little ultimate leavening effect in this type of flour mixture.

Essential conditions. If yeast plants continue to multiply, as they must in fermenting bread dough, and if they continue to carry on their life activities, including the making and functioning within their cells of various enzymes, they must be kept warm and they must be continually provided with water and other nutrients. These nutrients include mineral salts, soluble nitrogen compounds, sugars, and certain vitamins.

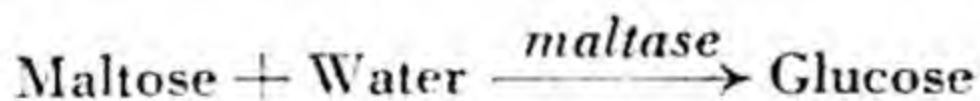
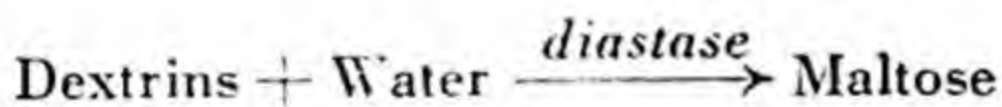
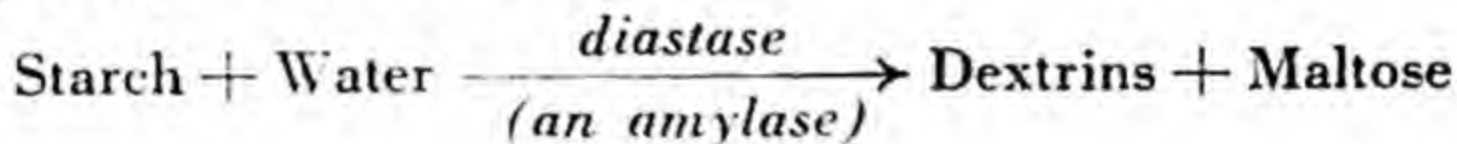
The *temperature* that is suitable for dough fermentation by yeast lies within the range from 75 to 95° F., the best condition probably prevailing at about 85° F. With the exception of sugars, *nutrients* are supplied in adequate amounts by flour and by milk if the latter is used instead of water. Sugars (p. 100) are made as products of hydrolysis of the flour's starch component. But in order to provide for an immediate beginning of fermentation, sucrose is usually introduced into the flour mixture as an added ingredient.

The actual fermentation. The expression "fermentation" is frequently used in an over-all capacity in respect to the whole series of reactions toward the ultimate making of carbon dioxide: reactions in which yeast plants participate in ways that are vital to their existence and for which they pro-

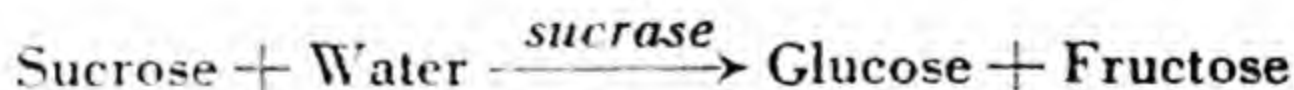
vide accelerating catalysts or enzymes. However, in the final analysis, "fermentation" actually applies to the particular end reactions during which carbon dioxide is made from monosaccharide sugars: from glucose as the end product of starch hydrolysis; from both glucose and fructose as products of the hydrolysis of sucrose. And, of course, it is the carbon dioxide—gaseous end product—that is of consequence in the aeration or leavening of the bread dough.

(1) The series of reactions that lead to the making of the single monosaccharide (glucose) from starch, (2) the reaction for the production of the two monosaccharides (glucose and fructose) from sucrose, and (3) the final fermentation reactions involving these monosaccharide sugars are represented in the following word equations. Specific enzymes for the speeding of these reactions are also given; with the exception of diastase they are made in yeast cells:

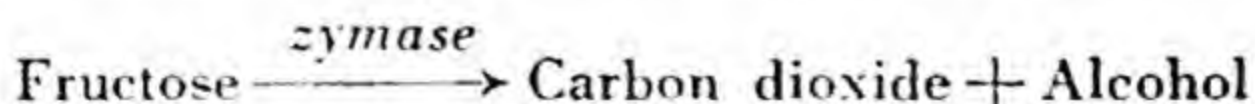
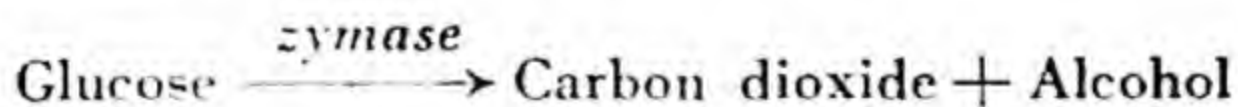
(1) Hydrolysis of starch



(2) Hydrolysis of sucrose



(3) Fermentation



Diastase is the term that has come to be applied to the specific amylase (starch-digesting enzyme) which is present in the wheat kernel, also in kernels of other cereal grains. It persists in flours during milling and develops into an active enzyme when flour is moistened and warmed.

Length of dough-fermentation period. Fermentation should be allowed to continue until the dough is about double its original bulk. By this time gluten is beginning to lose some of its elasticity so that a deep depression made in the dough, as with the finger, persists. If fermentation is continued much beyond this point, when so tested, the entire mass of dough collapses, indicating a weakening of gluten structure. If fermentation is *unduly* prolonged, acids are formed which impair the flavor of the baked bread.

The time required for the dough to become double in bulk is influenced by a number of factors, chief among which are: (1) temperature of dough, the rate of yeast-enzyme action being speeded with increased temperature; (2) stiffness of the dough, stiffer doughs requiring slightly longer times for fermentation than softer doughs; and (3) proportions of yeast and sugar, larger amounts of carbon dioxide being formed in a given time as these two ingredients are increased in proportion to quantity of flour specified in the recipe.

In regard to proportions of yeast and sugar, it should be stated that in all instances where a relatively large amount of yeast is used, the dough should also contain a relatively large amount of sugar in order to provide an adequate supply of this yeast nutrient. However, too large an increase in sugar should be avoided, since beyond a certain amount (approximately $2\frac{1}{2}$ tablespoonfuls of sugar when 2 yeast cakes are used for each 3 cupfuls of flour) the activity of yeast enzymes tends to be inhibited and the time for dough-fermentation is prolonged rather than shortened.

Shaping. It is in this step that the fermented dough is kneaded slightly in order to break up large gas bubbles and is then molded into the shape that is desired for the finished product.

Pan fermentation. The chief object of pan fermentation is to allow time for further leavening of the dough mass through continued making of carbon dioxide, until it reaches, approximately, the size expected in the baked product. Some

further modification of the gluten framework also occurs during this period. The temperature environment for pan fermentation may be the same as that used for fermentation in the dough.

Baking. Yeast breads should be baked at about 400° F. or slightly above this temperature. When placed in the oven the temperature throughout the dough rises gradually, with the result that during the early baking period all reactions that have to do with the making of carbon dioxide are greatly accelerated; these reactions continue until the dough mass reaches temperatures at which all enzymes are destroyed and fermentation ceases. But by this time another aeration factor has come to be effective, since all gases held captive within the pores of the dough—carbon dioxide, air, and water vapor—expand as they become heated, and in their expansion they carry the bread mixture upward; this expansion continues until the proteins of the dough are coagulated and the gluten has lost, thereby, its stretching ability.

The increase in dough volume in the oven is called *oven-spring*, which, if it is to be just sufficient to give desired size to the baked product, must be controlled by proper adjustment of oven temperature. This is usually accomplished at the recommended temperature of approximately 400° F. If more or less oven-spring is desired, the baking temperature should be respectively slightly lower or slightly higher than this temperature.

Accompanying the *coagulation of the proteins* of the dough mass during baking a slight *gelatinization of dispersed starch granules* occurs. This is limited in extent because of the relatively small amount of water that surrounds these granules as they are held embedded in the gluten mesh. Also during baking, *fats melt*. At surface areas, *starch dextrinizes* and *sugar caramelizes* to impart a golden brown color to the crust. Finally, the whole loaf gives out the odor and acquires the taste that is characteristic of baked yeast breads.

Care after baking. The final yet very important step in

the making of yeast breads is care of the product after it is removed from the oven. In order to avoid sweating at the bottom and sides of the loaf, it should be removed immediately from the pan in which it was baked so that air can circulate freely around it, thus providing for evaporation of any excess surface moisture. When thoroughly cool, the loaf should be kept in a covered but well-ventilated container in a cool, dry place.

Characteristics of a good loaf of bread. The finished loaf of bread should be symmetrical in *shape* with a well-rounded, smooth top. The *crust* should be an even golden-brown in color, slightly darker on the top than on sides and bottom; it should be crisp yet tender, and of about $\frac{1}{16}$ to $\frac{1}{8}$ of an inch in thickness. The *cut surface* of the loaf should be white or slightly creamy in color with no suggestion of a gray cast. The holes or cells, which constitute the *grain* of the bread, should be small, elongated from bottom to top of the loaf, evenly distributed, and surrounded by very thin walls. The *texture* of the crumb should be springy when pressed between the fingers and should have a tender, not tough, feeling when broken; in the mouth it should suggest neither dryness nor doughiness. And, finally, the *flavor* should be pleasant.

Variety in yeast breads. Variety in yeast breads can be obtained by the use of various kinds of wheat flours or by the substitution of whole wheat flour or rye flour for part of the white wheat flour. But the substitution should be only "in part" inasmuch as whole wheat flour contributes relatively less gluten in proportion to total volume of flour than do refined flours; rye flour does not supply any gluten at all.

QUICK BREADS

Flour mixtures which are designated as *quick breads* include such a wide variety of products that any attempt to classify them according to common characteristics becomes difficult. To name only a few of these products, they include:

griddle cakes, popovers, waffles, muffins, and gingerbreads. Quick breads are different, one from the other, in various ways: in ingredients used in their making; in proportions of ingredients used and manner of mixing; in conditions of baking; and in the appearance and flavor of the finished product.

Leavening action, how produced. (p. 78.) In contrast to the slow leavening of yeast breads, that of quick breads is completed within a brief period of time. Indeed, *quick-leavening* is probably the most common characteristic among flour mixtures of this class.

The rapid leavening of quick breads is brought about as follows: (1) by incorporation of air bubbles throughout the mass during the mixing period, and expansion of this entrapped air, presently, as the flour mixture is subjected to the baking process; (2) by changing of the water ingredient in every part of the mixture into steam during the baking; (3) by providing for incorporation, throughout the mass, of carbon dioxide both during the mixing period and, to some extent, during the baking.

Usually, all three aerating agents—air, steam, and carbon dioxide—contribute to the over-all leavening action in quick breads. But there are exceptions. One of these is in the instance of popovers, in the making of which water is present in such a large proportion in respect to flour that the steam, made in every part of the mixture during its baking, provides for sufficient leavening.

Ingredients. Quick breads contain flour, salt, fat, and water (usually supplied by milk), and may contain in addition sugar, egg, and various other ingredients.

Flour and development of gluten. All-purpose flour is the most desirable kind to use in the making of quick breads. The role of gluten, like that which it plays in yeast breads, is for the purpose of supplying framework for the product. But, in quick breads, because of the rapid leavening characteristic of this type of flour mixture, gluten strands are not

called upon to sustain the slow, prolonged stretching action that takes place in yeast breads; therefore the quality of gluten for quick breads with respect to elastic and cohesive properties is less important. The extent of the development of the gluten (p. 75) during the mixing process should depend upon the character of the quick bread desired. A discussion of development procedures for muffin and for biscuit types of quick breads follows. But first it should be said that never, in any of these mixtures, should the mixing technic be such as will bring about too extensive a development of the gluten; if this does occur, the grain of the crumb of the baked product will be inferior and the texture tough.

Development in muffin type of mixture. Over-development effects are well illustrated in flour mixtures that are represented by carelessly made plain muffins. If the batter for such a mixture is stirred beyond the point at which it still retains a rough appearance and consistency, the baked product, when broken open, will show a grain with long, tunnel-like passages which extend from the bottom of the muffin and converge toward the center at the top. The crumb will be tough in texture.

Although this tunneled type of grain is most frequently encountered in muffins, it will also occur in the baked products of other quick breads, the batters for which have been submitted to an over-mixing procedure.

Tunneling effect explained. One explanation of "tunneling" in flour mixtures of the muffin type is as follows: When over-development occurs gluten strands, becoming firmer, offer resistance to the expanding gases (air and carbon dioxide) entrapped within the mesh. But, in baking, when these gases become hotter, they, together with the water vapor, build up sufficient pressure so that they push upward *in spurts* leaving paths in the now partially coagulated gluten meshwork. The tunnels tend to converge toward the center at the top of the muffin because the batter in this region, not being as hot, hence not as far toward coagulation as that in contact with the metal of the baking dish, offers less resistance to the pressure of upward-pushing gases. The firm

character of the over-developed gluten is responsible, too, for the tough quality of over-mixed muffins.

Biscuit type of mixture. In contrast to muffins and other quick breads of the batter type, a biscuit dough should be kneaded slightly after the ingredients are mixed. In assembling this type of mixture, fat in solid form is first cut into the flour before the dough is made. This method of introducing fat tends to distribute it in layers among flour particles so that only short strands of gluten are formed in the dough, with the result that there is little cohesiveness to the gluten mesh. Hence, some development, as induced by kneading, is desirable in order to increase the firmness of the gluten strands, to the extent that they are able to entrap expanding gases during baking of the biscuits, rather than letting them (the gases) slip out from the loosely adhering gluten mesh. As a result, slightly kneaded biscuits rise to greater heights than do those not handled in this way.

Popovers. Popovers are unique among quick breads in that the batter from which they are made has so large a proportion of liquid to flour that, as gluten strands are formed, they become too dispersed to gather into a mesh-like structure. The thin popover batter is introduced into a very hot oven (450° F.) which raises the temperature of the contained water so quickly that there is rapid formation of a relatively large amount of steam. This carries the major portion of the mass upward with such speed that the baked product has an almost hollow interior surrounded by a crust of coagulated protein. Thus it is that popovers require only steam as leavening agent.

Water an important component. As with all flour mixtures water, of course, is the liquid that is employed in the making of quick breads. Occasionally it is supplied by adding just water, but more commonly it is introduced with milk; in some instances, however, the water required is obtained by the introduction of molasses, of which it is the liquid component.

As with yeast breads, water, together with glutenin and gliadin of flour, makes possible the gluten formation, and it dissolves all soluble components. In quick breads, water also functions to provide a favorable medium for reaction between components of baking powder, whereby carbon dioxide is made as leavening agent. The leavening action that is due to vaporization of water to steam during the baking of quick breads has been stressed previously (p. 104).

Other ingredients. In making quick breads, in addition to flour and water, or milk, and in most cases some material to supply carbon dioxide, salt should always be included in order to obtain the most flavorful product. As for other commonly used materials—sugar, egg, and fat—their inclusion among ingredients depends upon the particular type of flour mixture that is being made. The quantities of these latter ingredients are usually relatively small. Again, popovers are an exception, since they include such a high proportion of egg as to make egg proteins, instead of gluten, contribute in large measure to the characteristic structure of the finished product.

Variety in quick breads. Variety in quick breads becomes possible by using flours other than those from wheat, but under the same restrictions as apply to these substitutions in the making of yeast breads (p. 103).

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CHAPTER IX

FLOUR MIXTURES II—CAKES—PASTRY

CAKES

Two general classes. Cakes are distinguished from other flour mixtures by the fact that they contain larger proportions of fat, sugar, and egg in relation to the basic flour and water (or milk); consequently they are sweeter in taste and more delicate in texture. Hundreds of different cakes are made possible either by varying the proportions of these several ingredients or by incorporating in the batter other materials such as chocolate, spices, fruits, and nuts. In general, however, all cakes fall into two classes: (1) cakes with fat and (2) cakes without fat. Aside from the difference as to fat content that is implied in the class specification, *cakes with fat* include among the ingredients milk (or occasionally just water) and, as a rule, either baking powder, or baking soda with an acid, as the source of carbon dioxide. In contrast, *cakes without fat* do not contain water, other than that supplied by eggs, and they rely for leavening mainly upon air incorporated by means of beaten eggs.

Cakes with fat. The basic difference among cakes in this class lies in the proportions of fat and egg in relation to flour used in their making; plain or lean cakes contain relatively small quantities of these ingredients, rich cakes larger quantities, while in pound cakes fat and egg reach maximum proportions.

Type of flour used. In contrast to yeast breads and quick breads, the preferred flour for cake-making is milled from *soft wheats*, ordinarily of the soft red winter and soft

white wheat classes (p. 71). This flour is a short-patent type (p. 68), meaning that only streams from central portions of the endosperm of the wheat kernel are assembled to make it; it is sifted through very fine-meshed sieves and so contains only fine and evenly granulated flour particles; finally, the flour is usually bleached with chlorine.

Because of these carefully controlled factors in their manufacture, cake flours have a higher starch and lower protein content than all-purpose flours; also, coming from soft wheats, the gluten produced from them is less elastic and less cohesive in character. They are smooth and velvety in appearance and "feel," and are white in color.

Character of gluten. In cakes, as in all flour mixtures, gluten constitutes framework material; but less gluten is needed for this purpose with cakes than with yeast breads or quick breads because coagulated proteins of eggs also contribute to the supporting structure. Also, and of great importance, for cakes the *quality of the gluten should be weak*, that is, the gluten *as developed* (p. 75) during the stirring of the batter should not become very elastic or very cohesive, nor should it become too firm. A gluten of this character as derived from soft wheat flour will give a baked cake of fine grain and velvety texture. This is in contrast to a cake, coarser in grain and harsh in texture, which is apt to result from the use of all-purpose flour, the strong gluten of which leads to a framework that is excellent for quick breads and pastry but undesirable for cakes.

If all-purpose flour is used. But it should be said at once that, should cake flour not be available or be deemed too expensive, all-purpose flour with slight adjustment can be used for making cake and with very good results. One such adjustment is the substitution of a small amount of cornstarch for an equal amount of all-purpose flour, thereby diluting the stronger gluten proteins. While the proportion of cornstarch used should vary with the strength of the all-purpose flour, the usual rule is to substitute 2 tablespoonfuls of cornstarch for

2 tablespoonfuls of flour in every cupful of all-purpose flour that is used instead of cake flour. Naturally, the substitution of starch for flour does not alter the actual quality of the gluten obtained from the all-purpose flour used, but if care is observed to limit the extent of final stirring given to a cake batter which contains this flour, too great a development of the stronger gluten can be avoided.

Fat. Any plastic fat of good flavor may be used in cake-making. Such fats, in contrast to very hard fats, can be easily softened with a spoon or other stirring device and made into a creamy mass with which sugar is easily blended. The process of blending fat and sugar, an early step in cake-making procedures, is called *creaming*. From a flavor viewpoint, butter is the preferred fat; margarine, too, is acceptable in this respect. Hydrogenated fats do not supply flavor but they have the desirable plastic property; also some of these fats possess the added advantage of having had air incorporated with them during manufacture, a factor which contributes to the over-all leavening of the cake batter.

Function of fat. As in other flour mixtures, the role of fat in cake-making is to impart tenderness to the finished product by preventing a too-coherent and too-firm gluten framework, an effect which increases with an increasing proportion of fat to flour. Moreover, along with the tenderness of texture produced, the presence of fat in favorable amount results in a cake of fine grain and good keeping quality. At the same time, too much fat in relation to other ingredients results in a cake which is too compact in grain to be desirable.

Sugar. Fine granulated sugar is usually used for cake. Occasionally a recipe will list brown sugar as the sweetening ingredient for the sake of the added flavor. But, owing to its soft texture, brown sugar is difficult to measure accurately; therefore directions should always be included in the recipe as to the firmness with which this sugar should be packed into the cup when measuring it.

Function of sugar. While the obvious reason for use of

sugar is to give sweetness to the cake, it also plays an important role in affecting grain and texture. One explanation of this influence is found in the peptizing action (p. 367) that sugar has upon gluten in the batter, as the result of which gluten strands become thinner, less firm, and less coherent. But with an overly high concentration of sugar the peptizing action on gluten is carried too far. When this happens, cell walls here and there within the structural framework, becoming too thin to withstand pressure of enclosed and expanding gases, will break and adjoining small cells will gather into large cells with thicker containing walls. The result is evident, the cake product will be coarse in grain and harsh in texture. The contour of such a cake will show a concave top and the crust will have a shiny, sugary appearance.

Proportion. Both for sweetness and for its peptizing action, the more desirable effects are obtained when the volume of sugar in the batter is one-half that of the flour or very slightly greater. When this proportion is exceeded, adequate quantities of liquid and egg must be present so that (1) the water thus provided will dilute the sugar to reduce its concentration and (2) the egg proteins, upon coagulation, will contribute their part to the structural material.

Eggs and their function. Eggs give flavor to cake and, if whole eggs or just yolks are used, they also impart a desirable slightly yellow color to the crumb. A more fundamental role of eggs, however, lies in the supply of proteins provided which, upon coagulation, supplement the gluten in forming the framework of the finished product. But, for a cake made with fat, this function of egg proteins must not be so pronounced, as it is apt to be if egg content of the batter is large, that the texture of the baked cake will be unduly toughened. Hence, in any instance in which the recipe for this type of cake does call for an unusually large egg content, a considerable amount of fat is also included in order to counteract any such toughening effect.

The foam from beaten egg white, when introduced into a

cake batter, aids in leavening the product. Toward this end the foam should be carefully introduced as the last step in the whole mixing procedure.

Finally, eggs with their considerable percentage of *water* contribute a portion of the required amount of this essential ingredient to the cake batter; because of this fact, richer cake formulas which call for a fairly large number of eggs usually include a relatively small measure of water or milk. The function of egg proteins in offsetting any excessive weakening of gluten framework, owing to the presence of too much sugar in the batter, is discussed in the previous section.

Milk and its function. Milk is the liquid ingredient most frequently used in cakes, as well as in all flour mixtures, to supply water for the following purposes: to bring about the formation of gluten in the batter; to act as dispersing medium for soluble materials; to provide a medium in which reaction between components of baking powder can take place toward the making of carbon dioxide; and to supply significant leavening action from steam formed during baking.

Mineral salts, vitamins, and other organic compounds of milk make valuable contributions to the food value of cake.

Leavening materials. Leavening action for cakes with fat is similar to that provided in quick breads (p. 104), with the exception that air plays a more significant aerating role because of the longer mixing procedure, hence the greater opportunity afforded for its mechanical inclusion.

Salt and other flavoring materials. Salt, although frequently not listed in cake recipes among specified ingredients, should always be included, since it adds to flavor of the product. Other flavoring materials are peculiar to the particular cake.

Summary—proportions of ingredients for cakes with fats. From the foregoing discussion of the special role that each ingredient plays in the batter of a cake made with fat, it becomes apparent that, for best results, there must be certain best proportions among the ingredients, or at least a fairly narrow range of best proportions, for production of a cake of

excellent quality. Several isolated instances have already been cited; but, for emphasis, a brief summary is given here of "rules" which will serve as a guide both for using recipes intelligently and for interpreting faults that are frequently encountered in cake-making:

1. The volume of sugar should not greatly exceed one-half the volume of flour.

2. The volume of fat should be approximately one-half that of sugar.

3. With volume of flour held the same:

a. As volume of sugar is increased over the proportion stated above, the volume of liquid should be increased.

b. As eggs are increased, the volume of fat should be increased.

c. As eggs and fat are increased, the volume of liquid should be decreased.

Mixing procedure for cakes made with fat. *Changes effected.* During the mixing of ingredients for a cake made with fat, gluten, as usual, is produced from glutenin and gliadin of wheat flour and the gluten strands formed contribute, in part (p. 74), to the framework structure of the cake. At the same time, this framework is rendered porous throughout its mass by means of innumerable, imprisoned bubbles of gas: numerous tiny bubbles of air caught during the mechanical process of mixing, and countless bubbles of imprisoned carbon dioxide gas, made from reaction between baking powder ingredients. Also, during mixing, fat, in a very finely divided state, and water, carrying water-soluble substances, become dispersed in every part of the batter.

As is true of all flour mixtures, any exact description of the *final* structure that is established in the batter must be admittedly vague, owing to the fact that little authoritative information is available at the present time.¹ But if propor-

¹ A recent and interesting study on this subject has been reported by Carlin, G. T., "A microscopic study of the behavior of fats in cake batters," *Cereal Chemistry*, Vol. 21 (1944), pp. 188-199.

tions of ingredients are correct and if the mixing process is carefully carried out, the resulting cake batter will be fairly viscous in consistency and of a uniformly smooth and velvety appearance.

Conventional method of mixing. There are many methods of accomplishing the mixing of batters for cakes made with fat, but only one—that termed the conventional method²—will be discussed here. In this procedure:

1. Fat and sugar are creamed together until thoroughly blended.

2. Then, the eggs—whole and unbeaten, or just yolks if the whites are to be incorporated later as a foam—are stirred in, one at a time.

3. Next, the mass thus obtained is stirred and beaten until it is light and fluffy in consistency.

During these steps so much air becomes dispersed in the mixture that it contributes in large measure to the leavening action.

4. Next, the remaining dry ingredients sifted together (flour, salt, leavening material) and milk are introduced alternately, in small portions, with only sufficient stirring after each added portion to just blend it with the batter.

5. Flavoring is introduced next and the whole batter is finally stirred from about $\frac{1}{2}$ to 2 minutes. (See following paragraph for *final mixing time*.)

6. If egg whites have been reserved, they should be beaten to a foam which is now mixed with the batter in a folding technic, care being taken not to release any undue amount of air.

The final mixing time. The length of final mixing time that is most desirable for any given cake batter is influenced by a number of factors as follows: (1) A shorter time should

² For a description of other methods for mixing cake ingredients the student is referred to articles appearing in current journals or to publications of fat-and-flour-manufacturing concerns.

be observed when an all-purpose flour is used instead of a cake flour. As pointed out previously (p. 105), this is for the purpose of avoiding excessive development of the gluten framework which would result in a tough-textured cake. (2) Batters for rich cakes—those with relatively large proportions of fat and sugar—always require a longer final mixing period, the greater development of the gluten framework being counteracted to some extent by the presence of dispersed fat and by the peptizing action of sugar upon gluten strands (p. 111). (3) Finally, the irrespective of type of flour or richness of cake, if either a tartrate or phosphate type of baking powder is used, it is better to stir the batter for a short time in order to avoid excessive loss of carbon dioxide, which begins to be produced immediately upon introduction of these types of leavening agents.

Baking. After the cake batter for a cake-made-with-fat is mixed, it should be placed immediately into greased pans for baking. Moderate oven temperatures are best, ranging from 350 to 370° F. In general, lower baking temperatures are used for large-sized cakes, whereas temperatures of from 365 to 370° F. are suitable for layer and cup cakes.

Care after baking. Cake is “done” when the surface near the center rebounds quickly if touched lightly with the finger and when the cake begins to shrink from the sides of the pan. It should then be removed from the oven and allowed to cool in the pan for from 10 to 15 minutes depending upon size of cake. The cooling period is necessary in order to give time for the cake structure, which is extremely delicate while hot, to become slightly rigid so that it is not damaged when the cake is taken from the pan.

Cakes without fat. Cakes without fat include those of the foam or sponge type, such as angel and sponge cakes. *All water is supplied by eggs*, which these cakes contain in large proportion. They are *leavened both by air*, which is incorporated with the batter in large amounts by special mix-

ing technics, *and by steam*, which is formed in every part of the mixture during baking. As the term "sponge" implies, the baked cake has a delicate sponge-like texture, which is due to a framework structure composed mainly of coagulated egg proteins, with gluten playing a minor role.

Ingredients. Eggs play a very important part in cakes made without fat; either whole eggs are used, as in sponge cake, or just whites, as in angel cake. Other ingredients are sugar and flour, salt, and some other flavoring material. For angel cake cream of tartar is always included. Soft wheat flour is preferred; sugar should be finely granulated; and eggs of good quality are essential.

Mixing technic. No attempt will be made here to describe the various methods that are used for mixing foam-type cakes. Instead, attention is given only to two essential features that are common to all mixing procedures for such cakes: *first*, the making of a stable foam of egg white; *second*, the blending of this foam with the remaining ingredients in such a way as to maintain its stability. These features are essential since, as has been said, the egg white foam introduces the *leavening agent*, air, while the protein contributes largely to the *framework* of the cake.

Making a stable foam with whites of eggs. During their beating, myriads of air bubbles become entrapped throughout the egg white to form the foam. As beating is continued, some of the protein in areas that surround these air bubbles becomes somewhat coagulated to give them firmer containing walls. As a consequence, the tendency of the dispersed air bubbles to coalesce is decreased and the foam is rendered more stable. (p. 371.) But this effect can be carried too far; since, if beating is prolonged until the foam appears stiff and dry, the protein enveloping the air bubbles coagulates to such an extent that the walls of the bubbles lose their elasticity, with the result that, instead of stretching, they break when the enclosed air expands during baking of the cake. This causes a collapse of the foam structure of the cake to give a product,

reduced in volume, with a grain so compact as to be considered undesirable.

It follows that the technic employed in beating egg whites should be such as will bring about just enough coagulation of proteins surrounding the dispersed air bubbles so that the bubbles (1) are stabilized in the foam, but (2) still have walls sufficiently elastic to withstand reasonable expansion of their contained air. This degree of coagulation is accomplished by beating the whites to the point at which the foam stands in well-defined peaks when the beater is *slowly* withdrawn.

For angel cake, the cream of tartar is added to the egg white soon after beating is started. It exerts a slight stabilizing effect upon the resulting foam.

Blending procedure. The method used for blending the egg white foam with other ingredients in this type of cake is usually that of cutting and folding, since this technic is less apt to cause damage to containing walls of the foam's dispersed air bubbles than would result from a stirring technic.

Baking. For best results, baking of a foam-type cake should take place at a moderate temperature, so that egg proteins near the surface of the batter are not coagulated until sufficient heat has reached the center of the mixture to coagulate the proteins there also. This condition is attained at oven temperatures of around 325 to 350° F. Lower temperatures cause too much drying out of the cake; higher temperatures, although sometimes recommended, cause excessive browning of the surface even though the baking time is much shortened.

Angel and sponge cakes should be baked in ungreased pans so that the batter, as it expands during baking, will have a surface to which to cling. This contributes somewhat to the lightening effect by reducing the chance of any drawing-away of batter from sides of the pan as would be the case if these surfaces were greased.

Care after baking. Upon removal from the oven, this

type of cake should be inverted and allowed to remain in the pan until it is cold, when it can be easily removed.

Characteristics of a good cake. Irrespective of whether the cake is of the made-with-fat or made-without-fat type, a good cake is symmetrical in shape, with the surface very slightly rounded, but neither peaked nor concave. The top crust is an even golden brown and fairly smooth, with just a suggestion of roughness. The crumb of the cake, as shown by the cut surface, has an even distribution of cells with thin walls denoting a good grain. The cells are very small in pound and rich cakes, but slightly larger in plain and in foam-type cakes. There is an even color to the crumb over the whole surface of the cut slice of a good cake, and the crumb has a brightness which is imparted by light reflected from the many cell walls. The texture of the crumb, when touched with the finger, feels velvety, not rough, and it is slightly elastic but not rubbery. In the mouth, the crumb texture is tender, smooth, and moist; it is not tough, harsh or dry, nor does it have any suggestion of doughiness.

PASTRY

Although there are several types of pastry, including plain and puff pastry, it is *plain* pastry that is most frequently used, hence it is the only type that will be discussed here. This pastry, if properly made, is the delicate, tender product which is so popular for use in making the pies which serve as favorite American desserts. The ingredients—flour, salt, fat, and water—are the same as those used for the making of some quick breads; the difference, and that which gives the peculiar character to the product, lies in: (1) the proportion of these ingredients, (2) the technic used in their mixing, and (3) the subsequent handling of the resulting stiff dough.

Characteristics of pastry. Aside from a *pleasant flavor* in the finished product and its delicate *brown color*, plain pastry should be both *short* and *flaky*. A short pastry is one that is tender and offers little or no resistance to breaking.

A flaky pastry is layered throughout and tiny blisters show on the surface. A pastry which is short but not flaky is crumbly in feeling and unattractive in appearance; on the other hand a pastry which is flaky but not short, while attractive in appearance, is undesirably tough in texture.

Proportions of ingredients. All-purpose flour is the type that is well suited to pastry-making. For each cupful of flour used in preparing plain pastry, $\frac{1}{4}$ to $\frac{1}{3}$ cupful of a *plastic* fat and approximately 2 tablespoonfuls of cold water are required. If the fat is unsalted, $\frac{1}{2}$ teaspoonful of salt is a good proportion to use. A *range* for the measure of fat is given in order to provide for the variation among different fats in respect to shortening action (p. 134), the smaller amount being satisfactory to use with lard and the larger amount suitable for use with hydrogenated fats. If either butter or margarine is used, the $\frac{1}{3}$ cupful measure can well be slightly exceeded.

Mixing and handling. Since the short and flaky qualities of good pastry are in large measure dependent both upon the amount of gluten formed in the dough and upon the extent of its development, the mixing and handling technics, which are designed to control these factors, are of utmost importance. These are discussed as follows:

Fat should be cut into the flour, to which salt has been added, until it is finely divided and intimately distributed among flour particles. With this accomplished, when water is introduced as the next step in the procedure, a limited amount of gluten is formed in short strands with bits of fat between them. This distribution of fat in respect to gluten is important, since, upon further handling, the gluten cannot be easily developed into a coherent network, which, while essential to other types of flour mixtures, is not desired in pastry. *The rolling procedure* that follows serves three purposes: (1) the dough is shaped for the particular use for which it is intended; (2) the short gluten strands and fat particles between them are flattened in the dough to give it a layered

effect; (3) more or less air is mechanically entrapped between successive layers throughout the dough. Finally, the pastry is subjected to a high temperature for baking, 425 to 450° F., with the result that contained air and water vapor in rapid expansion push and hold the layers of dough apart, until their gluten component is coagulated and made rigid. This treatment creates the layered and blistered effect that is characteristic of a flaky pastry.

In making pastry it is important that the dough be kept cold in order that fat, as it is being cut into the flour, may not become oily. If this does happen, the fat will spread so widely among flour particles as to prevent their contact with water to such an extent that too little gluten is made, and an extremely short pastry without the desirable flaky character results.

SUPPLEMENTARY READINGS

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CHAPTER X

FATS ¹

Fats, as is also true of carbohydrates and proteins, must of necessity receive repeated consideration in the study of foods. Therefore, it seems reasonable that, for greater personal satisfaction, a certain amount of general information concerning fats should become a part of the background of every person who is interested in food studies. Such general outlooks, although limited, as to carbohydrates and proteins are undertaken in other chapters. The first part of this chapter aims to perform a similar service for fats. A certain amount of the material covered is a matter of common knowledge; all is review for those with adequate background in chemistry. Even so, for every student an organized review is all to the good. The second part of this chapter deals with studies of fats in specific application to cookery. Also studies of fats in relation to cookery problems appear occasionally in other chapters.

Fats and fatty oils.² Some people apply the term *fats* to those which are *solid*, such as the fats of the cow, sheep, and hog, in contrast to *fatty oils which are liquid*, such as fats of olives and corn, and of cottonseeds. But from the standpoint of most physical and chemical properties, their chemical composition, their nutritive functions, and their uses in cookery—both solid and liquid fats belong to the one classification of

¹ Certain substances classed as *fat-like substances*, referred to here and there in this text, are discussed briefly in Appendix IV, p. 380.

² This term is for the purpose of differentiating oils which are fats from oily materials, such as kerosene, which are not fats.

fats. Consequently, from now on, this will be the term under which both varieties of fats will be discussed.

Sources. There is excellent evidence that fats of plants are made from carbohydrates—starches and sugars. The fats of animals are made either from fats of the food or from starches or sugars supplied by the food.

Distribution in animal body. Fats are present in the blood for the purpose of transportation to the various cells. They are found in active cells in small quantities, but are highly concentrated in fat-storage cells and in fat deposits around the vital organs, especially those which are subject to considerable motion: namely, the heart, kidneys, and intestine. Storage fat lies chiefly in layers between muscles and skin as subcutaneous fat, but it is also distributed in smaller quantities between muscles themselves, and within muscle structure (p. 196).

Functions. (1) There seems to be no question but that in active cells the chief function of fat is to provide substances which react with oxygen for the purpose of making energy that is essential to the living body. (2) The layers of subcutaneous fat serve as a protection for the body against mechanical injuries; they also provide insulation for preventing both undue loss of heat from inside the body and the penetration of cold from without. (3) The fatty tissues around vital organs help to keep them in place and cushion their movements.

Form emulsions. Fats are insoluble in water but they form very satisfactory emulsion dispersions in water when an emulsifying agent is present (p. 373). Outstanding among these agents that are used for promoting emulsion of fats in food preparations are starch and proteins, especially the proteins of eggs (pp. 175–177). For cleansing purposes, soap is such an agent. In the human animal, various emulsifying agents are provided for maintaining fat dispersion: starch and proteins from the food mass in the intestine; bile salts and proteins in the blood and cells.

Composition. All fats are composed of the *glyceryl*

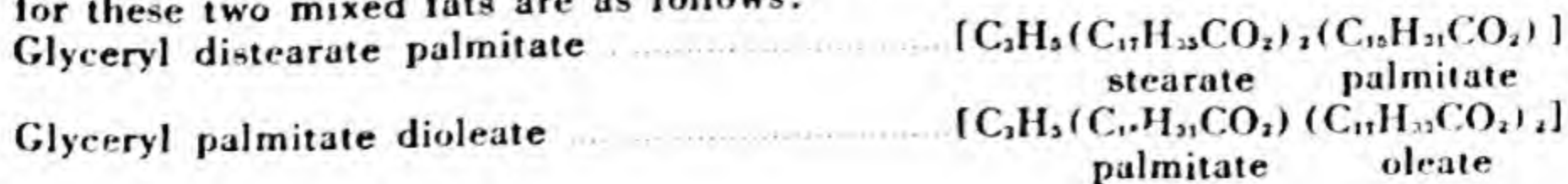
radical and *fatty acid radicals* in combination with each other. Since the glyceryl radical is a constituent of all fats, the latter are frequently referred to as *glycerides*. Although many fatty acid radicals are known to contribute to fats, the ones that predominate are the stearate, palmitate, and oleate radicals. The butyrate radical is important chiefly because it is a constituent of glyceryl butyrate, one of the fat components of butter. Fats containing these radicals are listed in the accompanying table; their common names should be noted since they will be used in later discussions:

COMMONLY OCCURRING FATS OR GLYCERIDES

Chemical name	Physical state	Common name	Formula
Glyceryl stearate	Solid	Stearin	$C_3H_5(C_{17}H_{35}COO)_3$ glyceryl radical stearate radical
Glyceryl palmitate	Solid	Palmitin	$C_3H_5(C_{15}H_{31}COO)_3$ palmitate radical
Glyceryl oleate	Liquid	Olein	$C_3H_5(C_{17}H_{33}COO)_3$ oleate radical
Glyceryl butyrate	Liquid	Butyrin	$C_3H_5(C_3H_7COO)_3$ butyrate radical

Natural fats are mixtures. Fats as they occur in plants and animals are mixtures of several different glycerides, with stearin, palmitin, and olein usually predominating.³ It will

³ In a fat the glyceryl radical is combined with three fatty acid radicals, as in glyceryl tristearate, usually called just glyceryl stearate [$C_3H_5(C_{17}H_{35}CO_2)_3$]. It is probable that animal fats are not straight glyceryl stearate or glyceryl palmitate or glyceryl oleate, but are what are called mixed fats, a term which, in this instance, does not mean a mixture of the fats just mentioned, but rather that a single glyceryl radical is combined with two or three different fatty acid radicals. Examples of mixed fats are (1) glyceryl distearate palmitate and (2) glyceryl palmitate dioleate. The first of these two fats is toward-hard because of the larger proportion of stearate radical; the second is a softer, toward-liquid fat because of the larger proportion of oleate radical. Formulas for these two mixed fats are as follows:



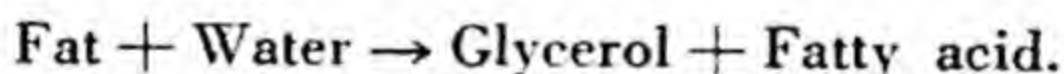
be noted in the accompanying table that stearin and palmitin are solid, while olein and butyrin are liquid. It follows, therefore, that the consistency of a natural fat must depend upon the proportion of these fat components that contribute to the fat mixture; and this is, indeed, the case. Thus:

Beef tallow, a hard fat, is $\begin{cases} 75 \text{ per cent stearin and palmitin} \\ 25 \text{ per cent olein.} \end{cases}$

Lard, a soft fat, is $\begin{cases} 40 \text{ to } 50 \text{ per cent stearin and palmitin} \\ 50 \text{ to } 60 \text{ per cent olein.} \end{cases}$

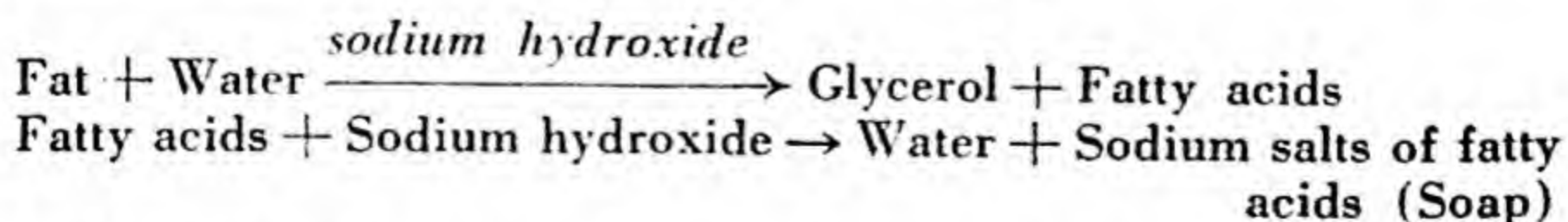
$\left. \begin{array}{l} \text{Olive oil} \\ \text{Cocoanut oil} \\ \text{Cottonseed oil} \end{array} \right\} \text{ liquid fats, are } \begin{cases} 75 \text{ per cent, or more, olein} \\ 25 \text{ per cent other fats.} \end{cases}$

Chemical behavior of fats. Hydrolysis. Fats react with water in hydrolysis to produce glycerol and fatty acids, but if the reaction is to take place with appreciable speed, without the aid of a catalyst, the fats must be very hot. Word equation for the general reaction is as follows:



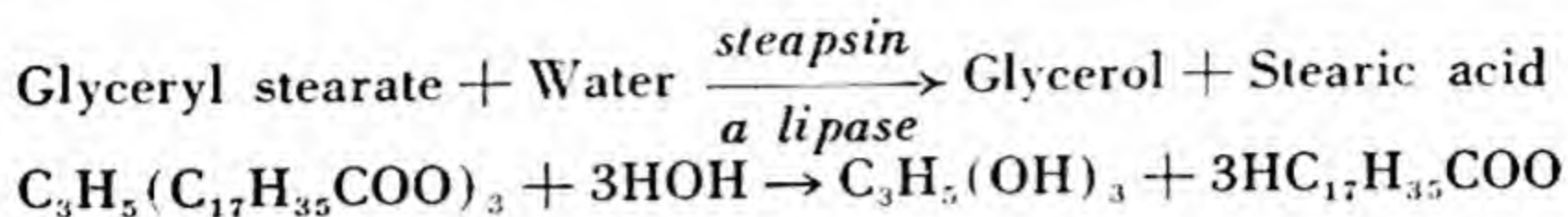
For accelerating the hydrolysis of fats to reasonable speed at easily obtained temperatures, a catalyst must be employed; this catalyst can be inorganic in character or an enzyme. For example:

For making soaps. In the presence of a base as catalyst, fat hydrolysis takes place slowly, but with reasonable speed, at 212° F. or thereabouts. This is important because, if sodium hydroxide is the base employed, not only does this base function as a catalyst for hydrolysis of the fat, but, following the hydrolysis, it reacts with the fatty acid produced to make a soap.



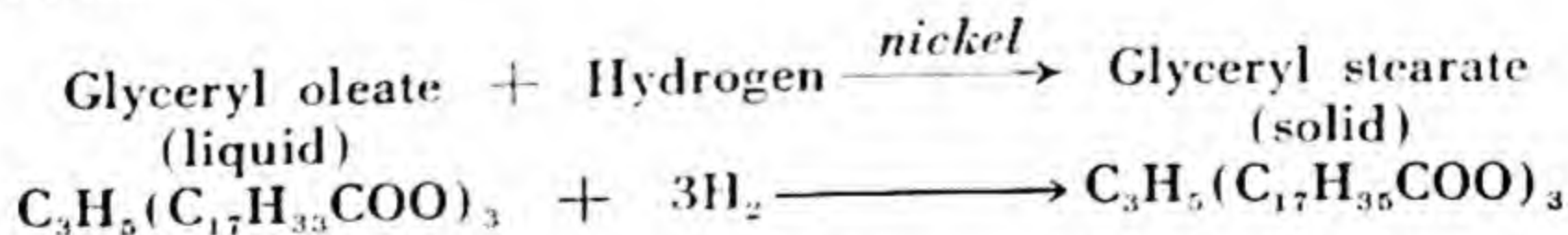
Of vital importance. Fat digestion is a fat-hydrolysis reaction which is greatly accelerated, even at body temperatures, by the presence in intestinal juices of the fat-digesting enzyme called

steapsin. Also, presumably, the first reaction step that takes place in the cells in fat catabolism is hydrolytic in nature with a lipase⁴ provided for causing the reaction to take place at reasonable speed. The following are word and formula equations for this reaction with glyceryl stearate as the specific fat concerned:



Hydrogenation of liquid fats.⁵ The two major uses that are made of fats are *for food* and *for making soaps*. But for both of these uses *solid fats are generally preferred*. It is true that liquid fats, such as those obtained from cotton-seeds, corn, and soybeans, have just as good food value as do solid fats, and some are, in fact, used as food; also liquid fats can be, and are, used for the making of soap; but even so, solid fats are generally preferred.

The chief difference in composition between a solid fat, such as stearin, and a liquid fat, such as olein, is that the hydrogen content of the solid fat is slightly higher than that of the liquid fat. But it has been found that under appropriate conditions, which include the presence of a favoring catalyst (usually nickel), most liquid fats will combine with hydrogen to make solid or semi-solid fats as products. Word and formula equations for one of these reactions are as follows:



This process is called fat *hydrogenation* and it has developed into an important manufacturing industry. The better

⁴ Lipase is the term applied to all enzyme catalysts for fat hydrolysis. Steapsin is a specific lipase.

⁵ This applies to liquid fats such as olein which are largely of plant origin but do occur to some extent in animal fats. It does not apply to the liquid fat glyceryl butyrate which does not combine with hydrogen.

grades of solid or semi-solid fats obtained thus are lard substitutes, and include Crisco, Spry, Snowdrift; poorer grades are used for making laundry soaps.

Rancidity of fats. Solid fats, like beef, sheep, and hog fats, have little tendency to become rancid. But butter does get rancid, as do olive, cottonseed, and other fatty oils. While there is no general agreement in regard to the cause of rancidity, there are certain features that are commonly accepted. Thus, it is agreed that the rancidity of butter is due, in considerable part, to the hydrolysis of glyceryl butyrate, the fat peculiar to butter. The products of the hydrolysis are glycerol and butyric acid, and it is to the presence of butyric acid that the odor of rancid butter is largely due. The rancidity of a fat mixture such as olive and cottonseed oils is probably, to quite an extent, the result of reaction between oxygen of the air and their liquid fat components to make substances with rancid odors and tastes.

FOOD FATS OF COMMON USE

Fats that are commonly used as foods are from various sources. *Animal fats* are obtained chiefly from meats and milk, from the latter through the use of both whole milk and the more concentrated fats of cream and butter. *Vegetable fats* that are generally acceptable for food uses are olive oil and oils from seeds and nuts. A discussion of various of these fats follows.

Butter. Over one-third of all the milk produced in the United States is used for making butter. In the year 1940, 2,244,000,000 pounds of butter were manufactured and the per capita consumption was 16.9 pounds.⁶

In the early days of this country butter-making was entirely an individual farm concern. Today, in contrast, by far the greatest quantities are manufactured in butter-making factories called creameries, located in central points in milk-pro-

⁶ *Agricultural Statistics*, United States Department of Agriculture (1946), p. 159.

ducing areas; dairy farmers sell to these creameries either their whole milk or the cream separated from it. As is well known, besides the butter output, large creameries are equipped to manufacture other products, which include cheese and dried skim milk, both of which are made from skim milk that remains after the cream is separated.

Butter-making. Cream for use in butter-making can be either sweet or sour, but always it must be cream of good quality as indicated by freedom from substances with off-flavors. Such substances may have been (1) transferred to the cream by way of the feed of the cow, or (2) made as the result of insanitary surroundings in the dairy, or (3) produced in the milk itself from action of undesirable micro-organisms.

Prior to the actual churning process, cream is pasteurized; if sour, before pasteurization, it is neutralized. A starter is introduced and the cream is held at approximately 70° F. for several hours in a process called *ripening*. The starter is a culture of bacteria of two types. One type functions in the making of lactic acid from lactose in the cream; the acid thus made produces a degree of acidity that is favorable to the gathering of dispersed fat globules into butter during the churning process. The second type of bacteria functions in the production of certain desirable, flavor-giving materials in the cream which persist in the butter; these substances are made from citric acid, which is always present in milk in small quantities.

When ripening has progressed far enough, the cream is cooled, in order to check bacterial action, and is then ready for churning at a temperature maintained approximately within the range of from 48 to 56° F. The churning process subjects the cream to a continuous agitation, in the course of which fat globules gather into granule-like masses of butter, which separate from the milky residue that bears the familiar name of buttermilk. The buttermilk is drawn from the churn; the butter is washed, salt is added, and the mix-

ture is "worked" for the double purpose of expelling excess buttermilk and effecting an even distribution of salt. During this treatment the butter takes on a firm, smooth, waxy consistency and is ready for packing into tubs or smaller-sized packages for distribution. According to federal law, butter must contain not less than 80 per cent milk fat by weight.

This description of butter-making is but a brief outline of a highly technical process which requires manipulative skills and a knowledge of numerous details, such as: required percentage of fat in the cream, degree of acidity that must be obtained before churning, temperature of churning in relation to that of the environment, and optimum speed of churning.⁷

Renovated butter or process butter. This product is made from butter of inferior quality. It is melted; the fat is then drawn off, purified, and rechurned with fresh pasteurized milk or cream. It is a wholesome product but the manufacturer must be licensed by the Bureau of Internal Revenue and must pay a tax on each pound sold.

Uses of butter. Because of its pleasant and distinctive flavor, one of the most common uses of butter is as a spread for bread. In cookery it imparts added flavor to cooked vegetables, and it is used in flour mixtures not only for shortening but for contributing to the flavor of the baked product. It can also be used as a frying medium (p. 131).

Margarine. Margarine manufacture in this country had its beginning about 1875; since then the industry has grown into a large and important concern. This product contains about 80 per cent fat. It is plastic in consistency, and of all fats it most closely resembles butter in flavor, doubtless owing to the fact that milk in some form is mixed with the fats used in its manufacture.

Manufacture. Fats used. Originally the chief liquid fat used was olein, which was separated from animal fats for this purpose. This practice probably accounts for the name

⁷ For details of butter manufacture the student is referred to sources listed at the end of this chapter.

oleomargarine which is the official name for the product as designated by the federal government. In due time, cocoanut oil, imported from the Philippine Islands, began to replace animal fats; but, more recently, cottonseed and soybean oils have come to take first place as fats for the manufacture of margarine, and at present one or the other of these oils, or a mixture of them, also other domestic vegetable oils, are used almost exclusively. In fact, in 1945 animal fats comprised only 3.8 per cent, while domestic vegetable oils comprised 96.2 per cent, of the fat used for making this butter substitute.⁸

Procedure. The manufacture of margarine involves preliminary purification of the fatty oil used in order to improve its color and flavor. This oil is then hydrogenated (p. 125) to produce a soft, solid fat which will have a desirable spreading quality. The hydrogenated fat is then mixed with pasteurized and cultured skim milk, with which it is churned until an emulsion of milk-in-oil is obtained which is margarine. Upon completion of the churning the margarine is hardened by chilling, then salted and worked to remove excess water, and finally packaged.

The cultured milk that is used in making margarine gives a slight butter flavor to the product. To intensify this flavor some margarines may contain an added butter-flavoring material; if so, the fact must be stated on the label of the package.

Fortified margarine. The addition of vitamin A to margarine, either in the form of fish-liver oils (p. 229) or their concentrates, while not mandatory, is a very common practice in the industry. According to federal law, if the vitamin is added it must be in amounts of not less than 9000 U.S.P.⁹ units of vitamin A per pound, and the label of the package must carry the information.

Since vitamin A is a natural component of butter, either

⁸ *Agricultural Statistics*, United States Department of Agriculture, 1946, p. 148.

⁹ United States Pharmacopoeia.

as vitamin A itself or its precursor, carotene, it is important when using margarine in place of butter to select a brand which has been fortified with this vitamin. If care is observed in this respect, it is quite generally agreed by experts that margarine and butter can be used interchangeably in the ordinary mixed diet with equal nutritional benefits.¹⁰

Lard. Lard is the fat that is separated from fatty tissues of the hog carcass by a process known as "rendering." Rendering involves subjecting the fatty tissues to a heating process by which the melted fat becomes automatically separated from non-fat material. The product obtained is very nearly 100 per cent fat. Several types of lards are manufactured, depending upon the rendering procedure and upon the location in the carcass from which the fatty tissues are taken. These types of lards are as follows:

1. *Kettle-rendered lard* is made by heating and stirring finely cut-up fatty tissues in a steam-jacketed, open kettle at temperatures ranging from approximately 230 to 260° F. Any water in the tissues is evaporated; non-fat materials settle to the bottom of the kettle; and melted lard is drawn off from the top.

Kettle-rendered leaf lard is made from "leaf-fat" tissues, that is, the fatty tissues which surround the vital organs of the hog. Lower temperatures are employed for the separation of leaf lard than those that are specified for the separation of lard from tissues other than leaf-fat tissues.

2. *Dry-rendered lard* is prepared in a manner similar to that by which kettle-rendered lard is obtained, except that the cut-up fatty tissues are heated in a closed, steam-jacketed tank equipped with an automatic stirrer which keeps the mass in constant agitation, and the heating is carried out under a partial vacuum. Rendering of the fat after this method is accomplished at lower temperatures and overheating is thereby avoided. Water is expelled through special vents and melted lard is drawn away from the residue.

¹⁰ Deuel, H. J., Jr., "The butter-margarine controversy," *Science*, Vol. 103 (1946), pp. 183-187.

3. *Steam-rendered, or prime-steam, lard.* For this type of lard, fatty tissues are mixed with water and heated in a tank at approximately 298° F. under a pressure of about 50 pounds. As the fat melts, it collects above the surface of the water at the top of the tank and is drawn off.

Refined steam-rendered lard is steam-rendered lard that has been refined by mixing and heating it with powdered fuller's earth or a similar material after which it is separated by filtration. This lard is whiter in color and more mild in flavor than lards that are obtained by the dry-rendering methods.

Oils and hydrogenated fats. In the United States many oils that are obtained from seeds are used for various cookery purposes, the choice of oil depending upon the particular food product being made.

Olive oil. This oil is pressed from the fruit of the olive tree. It has a distinct flavor the character of which makes it generally popular for use in preparing salad dressings.

Cottonseed, corn, soybean, peanut oils. These are among the oils that are separated from seeds of plants. After refining, the products are bland in flavor and can be used for almost all cookery purposes that do not require a plastic fat; they are used extensively in food industries.

Oils from these sources are outstanding among fatty oils that are either partially hydrogenated to make plastic fats used for shortening purposes (p. 134), or hydrogenated and subjected to further processing for the manufacture of margarine.

Hydrogenated fats. A brief discussion of the hydrogenation of fatty oils together with the reaction concerned has been presented in a preceding section of this chapter.

FATS AND COOKERY

Use of fats in frying. Frying is one of the most common uses of fat in the preparation of foods, since it is a method of cooking that can be adapted to almost all types of food materials—fish, meats, eggs, vegetables, and certain flour mixtures

such as griddle cakes and doughnuts. *Frying is the cooking of food in hot fat*: if the layer of fat in the frying pan is shallow, the process is called *sautéing or pan-frying*; if the hot fat is sufficiently deep to allow the food pieces to be submerged in it, the process is called *deep-fat frying*.

Both bland fats, such as lard, and flavorful fats, as exemplified by butter and margarine, can be used for the frying of foods, and they can be either solid fats or oils. Fats that remain from the cooking of fat-rich foods, such as bacon and sausage fats, can also be used for frying purposes, but more especially for *sautéing or pan-frying*; they are not well adapted for deep-fat frying use.

Frying temperatures. When fats are heated, as in both pan- and deep-fat frying methods, unless due precaution is observed to control the process, a temperature is reached at which a thin, bluish-white smoke rises from the surface. The temperature at which this occurs is the *smoking-point* of the fat, and it indicates that various reactions are taking place with increasing speed to produce substances among which are *fatty acids* and *glycerol*. Upon further increase in temperature a substance called *acrolein*, acrid in odor and irritating to the eyes, is made from the glycerol; this objectionable substance becomes evident when a fat is overheated. Smoking-point temperatures differ among fats and their determination has been a subject of study by various research workers.¹¹

Because changes in fats due to overheating are detrimental to the flavor of fried foods, it is of greatest importance to avoid heating them to their smoking temperatures. When food is being *sautéed*, this is not difficult since the appearance of smoke is easily detected. But with deep-fat frying, smoking-point temperatures should be given more consideration because, when cooking foods in this way, the fat must be heated occasionally to as high as 400° F. Temperatures that

¹¹ A recent study. Vail, G. E., and Hilton, R., "Edible fats and oils. Two chemical characteristics," *Journal of Home Economics*, Vol. 35 (1943), pp. 43-46.

are recommended for the deep-fat frying of various types of foods are listed in the accompanying table; and with a thermometer designed for such use these temperatures are easily maintained. However, inasmuch as a thermometer may not be always available, the table also includes a practical test. This test is in terms of the time that is required for browning a small cube of bread, each browning-time period being significant of a specific temperature of the fat concerned.

TEMPERATURE FOR DEEP-FAT FRYING¹²

Type of product	Temperature of fat		Approximate time required to brown a one-inch cube of bread in the hot fat
	<i>degrees F.</i>	<i>degrees C.</i>	<i>seconds</i>
Doughnuts Fritters Oysters, scallops, soft shell crabs Fish	350 to 375	177 to 190	60
Croquettes Eggplant Onions Cauliflower	375 to 385	190 to 196	40
French-fried potatoes	385 to 395	196 to 201	20

Shortening action. This use of fats is of great importance in the making of flour mixtures of all kinds. Shortening refers to that property of fat whereby it influences favorably the *texture* of a baked product which in yeast breads, quick breads, and cakes is described as *tender*, but in pastries and cookies is referred to as *short*. The way in which fats are believed to bring about the shortening effect has been dis-

¹² *Handbook of Food Preparation*, American Home Economics Association, Washington, D. C., 1946, p. 45.

cussed in connection with the preparation of various flour mixtures. (pp. 75, 96, 110, 119.)

Fats vary in shortening action. Plastic fats are best suited for making flour mixtures. But all fats differ with respect to the shortening effect that they produce in any given product—or, technically speaking, they differ in shortening value. Although the complete explanation of this variation is not at present clear, it is probable that it is due to a difference in inherent physical properties, particularly plasticity, of various fats and to the chemical make-up of the glyceride components that comprise the specific fat mixture (p. 123). But regardless of reasons “why,” the fact remains that, in general, among plastic fats, lards rank first in shortening value, followed by the various hydrogenated, vegetable fats, then by butter and margarine. *For making pastry* any one of these fats can be the sole fat used with satisfactory results, but a particularly pleasing flavor, as well as shortness, is obtained in the pastry by using a mixture of either lard or hydrogenated fat with either butter or margarine. *For making cakes*, it is wise to select a fat other than lard, for the reason that lard, although a plastic fat, does not possess the ability to cream well with sugar.

Fats and salad dressings. When fats are used for making salad dressings, such as French and mayonnaise dressings, it is their ability to form emulsions which is of importance. This property of fats has been explained elsewhere in this text (pp. 372) and need not be discussed further here.

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CHAPTER XI

PROTEINS

Occurrence of proteins. Proteins are very widely distributed in nature, being present in all plants and animals. They are components of all food materials, although, in the main, foods of animal origin—meats, fish, poultry, eggs, and cheese—provide more proteins than do those derived from plants.

Building units for proteins. The “building blocks” for all proteins are *amino acids*, twenty-one of which are known; moreover, all molecules of each specific protein are composed of the same assortment of amino acids—hundreds of them—assembled according to the same peculiar pattern. Plants are able to make their proteins from inorganic substances; whether they first make the amino acids and then build these into proteins or build the proteins direct from inorganic materials is not known; but it is certain that, once made, the units which comprise the plant proteins are amino acids. Animals are not as efficient in this way as are plants; they are not able to make either amino acids or proteins from inorganic substances. Therefore, since nature’s only source of amino acids is from proteins, this foodstuff, whether from plants or animals, must of necessity be a component of food mixtures for animals, including man.

For animals, then, a cycle of proteins-to-amino acids and amino acids-back-to-proteins must occur.

The proteins-to-amino acids part of the cycle involves reactions with water, in hydrolysis (p. 359). Protein digestion includes such reactions which begin in the stomach and are completed in



the intestine (p. 138). The amino acids-to-proteins part of the cycle is one of dehydrolysis (one type of dehydration) whereby hydrogen and oxygen, to form water, are removed from the amino acids as the result of which they combine to produce the protein molecule. In man this takes place in the myriads of cells which select the specific amino acids, and in such numbers, as are required for building their own characteristic proteins.

AMINO ACIDS

Composition. All carbohydrates and all fats are composed of just the three elements *carbon, hydrogen, and oxygen*. All amino acids have these three elements as constituents, but they must also contain *nitrogen*, and some of them contain the element *sulfur*. Since amino acids have certain chemical properties in common, it is reasonable to presume that their molecules have common structural features, but with the various amino acids differing from each other in some respects.

How many in natural proteins. Twenty-one¹ amino acids are known to contribute to the building of the proteins of plants and animals. As said previously, they are obtained from proteins through hydrolysis.

Nutritionally indispensable amino acids. All twenty-one of the amino acids, and probably others not yet identified, are essential for the building of body proteins of humans and of other animals. But it is known that at least *ten amino acids* must be provided in proteins of the food because the body is not able to make them from other amino acids or other organic compounds. These, therefore, are termed *nutritionally essential* or *indispensable amino acids*, meaning that of all amino acids, these *must* be present in the proteins of the food. Sherman says, “. . . if any one of the ten so-called ‘nutritionally essential’ or ‘indispensable’ amino acids is lacking in the amino acid mixture, normal growth will not occur. But if all ten of these are provided in suitable amounts, the body can form from them the remaining amino acids which enter into the composition of proteins.”²

¹ Some authorities claim that twenty-three such amino acids are known.

² Sherman, H. C., *Chemistry of Food and Nutrition*, 7th ed. Copyright, 1946, by The Macmillan Company and used with their permission.

PROTEINS

Proteins of foods. Proteins contribute to the synthesis of protoplasm within the cells of both plants and animals, and, after death, they persist in these cells, but probably in a somewhat altered state.

Although proteins are components of both plants and animals, animal tissues are much richer than those from plants in this essential foodstuff. Thus, lean meats, muscle parts of poultry and fish, cheese, and eggs are among foods with high protein content. The blood of animals also possesses protein components but, while blood does have food value, it is not commonly used as food for humans, save for the small portions that remain with the meat after the animal is slaughtered.

Composition. As stated previously, a protein is composed of many amino acids or, better said, of amino acid radicals, in that, when combined in the protein, they are deficient in hydrogen and oxygen (in proportions for making water). Many different proteins can be made from the same assortment of amino acids since the latter can be assembled in numerous different patterns, with the same amino acid radicals being repeated several or many times within the protein molecule structure.

Nutritional completeness of specific proteins. The terms "complete" and "incomplete" have come to be applied to proteins with reference to their nutritional efficiency, which depends upon the amino acid offerings of the protein. Accordingly:

1. A protein which contains all of the "nutritionally essential" amino acids in sufficient quantities, not only to maintain life of the animal but to provide for normal growth of the young, is a **complete protein**. Among such proteins are casein and lactalbumin of milk; ovalbumin of egg white and ovovitellin of egg yolk; edestin and glutenin of wheat.

2. But there are proteins whose over-all assortment of amino acids includes sufficient of those which are "nutrition-

ally essential" to maintain life but not enough both to maintain life and to provide for normal growth. These are called ***partially complete proteins***. Gliadin of wheat is such a protein.

3. A protein whose amino acid offering is not sufficient either for maintaining the life of the animal or for providing for growth of the young is ***nutritionally incomplete***. One of the proteins of corn, called zein, and gelatin are two incomplete proteins.

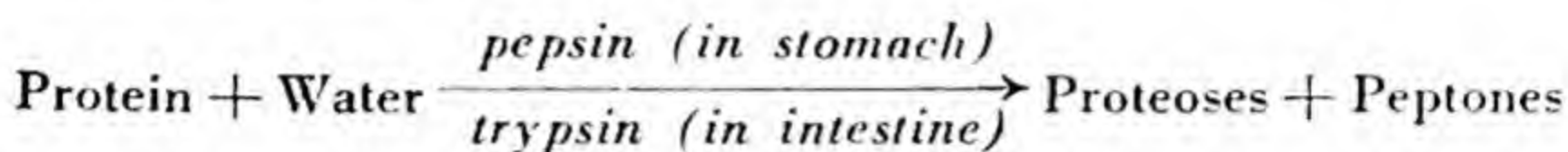
Mixtures of proteins in foods. The foregoing discussion is in respect to specific proteins that research chemists have been obliged to sort out from their mixed associates, through most intricate and painstaking procedures, as an essential preliminary before the proteins can be fed to experimental animals for the purpose of discovering the extent of their nutritional efficiency.

Actually, foods as provided in nature—in grains, meats, milk, eggs, etc.—contain several proteins so that any nutritional deficiency in one protein is quite likely to be compensated for by the others. For example: gliadin of wheat has been mentioned as a partially complete protein, but wheat has complete proteins, too; and wheat proteins, inclusively, furnish a good over-all supply of amino acids as to quantities while the complete proteins provide sufficient of those that are nutritionally essential. Nor should gelatin be regarded as valueless. To be sure, it is an incomplete protein hence in itself lacking in nutritionally essential amino acids, but it can be used advantageously along with other proteins that are complete.

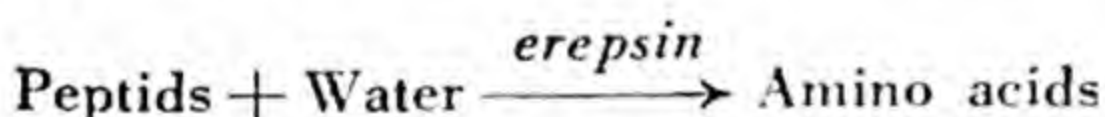
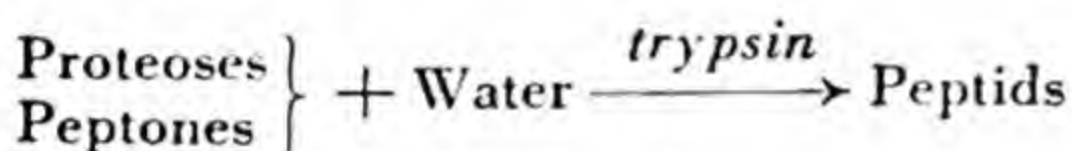
Digestion of proteins. As has been said, obtaining free amino acids from proteins involves hydrolytic reactions with water. Outside the body the reactions require many hours of long boiling in the presence of a strong acid such as hydrochloric acid. During the cooking of protein-containing foods, since such conditions are never obtained, very little, if any, hydrolysis of this foodstuff occurs. For digestion of pro-

teins, in the alimentary tract, at reasonable speed and at body temperatures, nature provides very effective enzymes. It is known that the reactions concerned take place in steps. Partial digestion of a portion of the protein of any food mixture takes place in the stomach with proteoses and peptones as products and pepsin as catalyst. But the major portion of protein digestion occurs in the intestine; products and functioning enzymes are indicated in the following equations for the reactions.

In both stomach and intestine



In intestine



And the thousands of amino acid molecules produced in this manner, after every meal in which proteins appear in any appreciable amounts, are absorbed into the blood stream and distributed to cells throughout the body.

Proteins and cookery. The proteins which predominate in foods and which must receive careful consideration in the preparation of foods are: the simple proteins *albumins* and *globulins*, provided chiefly in meats, milk, and eggs; the simple proteins *glutenin* and *gliadin* which are components of wheat; the albuminoids *elastin* and *collagen* of certain meat tissues; and the *phosphoproteins*, casein of milk and *ovovitellin* of egg yolk. (See Appendix V, page 382, on classification of protein.)

Procedures which are employed in cookery, with an eye to the properties of these proteins, are discussed in various parts of this text, notably in chapters which deal with meat cookery, with the making of bread-mixtures, and with the preparation

of other dishes which have as components eggs, or milk, or both.

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CHAPTER XII

MILK

History does not disclose with any certainty when milk of animals was first used for food. Records do show that from about 10,000 to 12,000 years ago Neolithic¹ man, living in the part of the world that is now Europe, had domesticated animals, and it is thought by some that the people who lived in that geological period were the first ones to drink milk. But whatever its history, it is certain that today milk holds a place of great importance among foods.

In different countries of the world this food is obtained from various milk-producing animals; but in this country, it is milk from cows that is chiefly favored, and it is a discussion of milk and certain milk products from this source with which this chapter and the following chapter are concerned. Hence, unless otherwise stated, the term "milk" will apply throughout to cow's milk.

In passing, it is a matter of interest to observe that in this as well as in other countries, while it continues to hold its justified place of first importance as a food, milk has come, also, to be the basic material for many industrial uses including the manufacture of paints, paper, and fabrics. In 1945,

¹ The *Neolithic Period* is also referred to as the *Smooth-Stone Period*, since in this period man had learned to use implements made from smooth stone instead of cruder ones from rough stone. This era was in process of development probably about 10,000 years ago; it was followed by the Bronze Age. In the Neolithic Period the climate of Europe had fully emerged from that of the glacial period and was much as it is today. People who lived in this era had learned to make pottery and to spin; they had domesticated animals; and they cultivated various crops, including flax, barley, and corn.

in the United States alone, more than 100 billion pounds of milk were produced.

Importance as food. The importance of milk as a food lies in its high nutritive value. It contains all six of the essential foodstuffs as follows: Its *proteins* are of excellent quality for growth and maintenance of body tissues. Its *calcium*, combined in both inorganic and organic compounds, is outstanding in quantity provided. Its *iron*, although small in quantity, is combined within compounds that are readily absorbed from the digestive tract and readily utilized in metabolic processes within the body. As for *vitamins*, milk is a rich source of vitamin A value (p. 178) and of riboflavin; also it contains other vitamins in lesser amounts. *Fats* provided in milk are readily digested upon entering the intestinal tract, since, being already emulsified within the milk dispersion, considerable areas are immediately in contact with the fat-digesting enzyme, steapsin. The carbohydrate of milk, namely *lactose*, is readily hydrolyzed in the intestine to the easily absorbed monosaccharides, glucose and galactose.

It is not surprising, therefore, that milk, together with milk products (see following table), comprises one of the eleven food groups that nutritionists recommend should, for optimum human nutrition, be included every day in the diet. The Bureau of Human Nutrition and Home Economics of the United States Department of Agriculture recommends as a standard for good nutrition² a daily allowance of 3 to 4 cup-

Milk Products—Equivalents to One Quart of Whole Milk

Skim milk	1 qt. plus 1½ oz. butter
Evaporated milk	17 oz.
Dry whole milk	4½ oz.
Dry skim milk	3½ oz. plus 1½ oz. butter
Cheese	5 oz.

² *Family Food Plans for Good Nutrition*, AW1-78, United States Department of Agriculture, Bureau of Human Nutrition and Home Economics, Agricultural Research Administration, 1943.

fuls of milk or its equivalent for every child, and about 3 cupfuls for every adult.

Sherman states that "Milk in one or more of its various forms may well be a part of every meal and . . . it is quite clear that a decidedly increased prominence of milk in the diet is an important step toward the best use of food, . . . and also of our national food-production resources."³

From a cost angle, Sherman also recommends that one-fifth or more of the total expenditure of the family food budget be spent for milk and cheese.⁴

Although one may obtain all of the nutritional benefits of milk from using it solely as a beverage, it is fortunate for variety's sake that milk lends itself to a vast array of cookery uses. It can thus become a part of one's daily diet in many different and attractive forms. In fact, milk, which is about 87 per cent water, is the liquid ingredient that is specified for use in a very large proportion of recipes for various food preparations. It may be used in small amounts in flour mixtures or in relatively large amounts in many desserts. And cheese, a milk product in which the milk solids are highly concentrated, is included as an important ingredient in many flavorful dishes that may well serve as part of the main course in simple meals.

Color and pigments of milk. The white color of milk is due to the scattering of reflected light (p. 365) both from the surfaces of finely emulsified fat globules and from molecule aggregates of colloiddally dispersed proteins and certain salts. The yellow color is due to the presence of carotinoid pigments (p. 237), chiefly carotene, which are dissolved in the fat globules; furthermore, since these carotinoid pigments are transferred to the milk fat from the food of the cow, milk is deeper yellow in color when the feed includes carotinoid-rich materials such as green grasses, green silage, or green alfalfa

³ Sherman, H. C., *Chemistry of Food and Nutrition*, 7th ed. Copyright, 1946, by The Macmillan Company and used with their permission.

⁴ *Ibid.*, p. 534.

hay. The presence of another pigment, originally called lactoflavin but now known to be the vitamin riboflavin, becomes apparent when whey (p. 146), to which this pigment imparts a greenish color, separates from the curd.

Foodstuffs present in milk. The average composition of market milk is as follows:

Water	87.0%
Proteins	3.3%
Carbohydrate (lactose)	5.0%
Fats	4.0%
Mineral salts	0.7%
Vitamins	?%

Market milk, as a rule, is a mixture of milk from many cows of different breeds and from different herds of cows which receive variations in care and feeding. Deviations from the average figures are greatest in respect to the fat and protein components. They are brought about by several factors, the most influential of which is the breed of cows. Jersey and Guernsey breeds, for example, give milk with highest fat and protein contents, while the milk of Holstein cows has the least amounts of these two foodstuffs. Irrespective of breed, however, milk becomes richer in fat as the period of lactation advances; also, other things being equal—breed, period of lactation, care, and feeding—winter milk contains a larger percentage of milk fat than does summer milk.

Character of the dispersion. In the system which is so commonly and so easily referred to under the over-all term of “milk” one is actually dealing with a very complex dispersion. Water is dispersing liquid. It holds *in true solution* the lactose, some of the inorganic salts including soluble calcium salts, and the water-soluble vitamins. This solution, in turn, holds the proteins and less soluble calcium phosphates *in colloidal dispersion*, and the tiny fat globules *in suspension*. Finally, within the dispersed fat globules, fat-soluble vitamins and carotinoid pigments are distributed *in true solution*.

PROTEINS OF MILK

Casein. Nutritionally, casein is a complete protein (p. 137). It is the chief protein of milk and constitutes about 3 per cent of the whole. Actually, casein is a phosphoprotein (p. 383) which contains a protein and phosphoric acid in combination with each other (Fig. 8).



Fig. 8. Diagrammatic representation of the casein molecule.

Although in fresh milk casein is in fairly permanent colloidal dispersion, it is easily precipitated by the presence of either an acid or the enzyme rennin. Either of these agents—an acid or rennin—causes casein micelles to aggregate and precipitate. This clustering of the micelles is called coagulation, and when it occurs the milk is said to be coagulated or curdled.

Several well-known and undesirable evidences of the precipitation tendency of casein are encountered in cookery when curdling occurs in the making of milk dishes. On the other hand, there are desirable effects of this property of casein, among them the making of rennet puddings and the many and various cheeses.

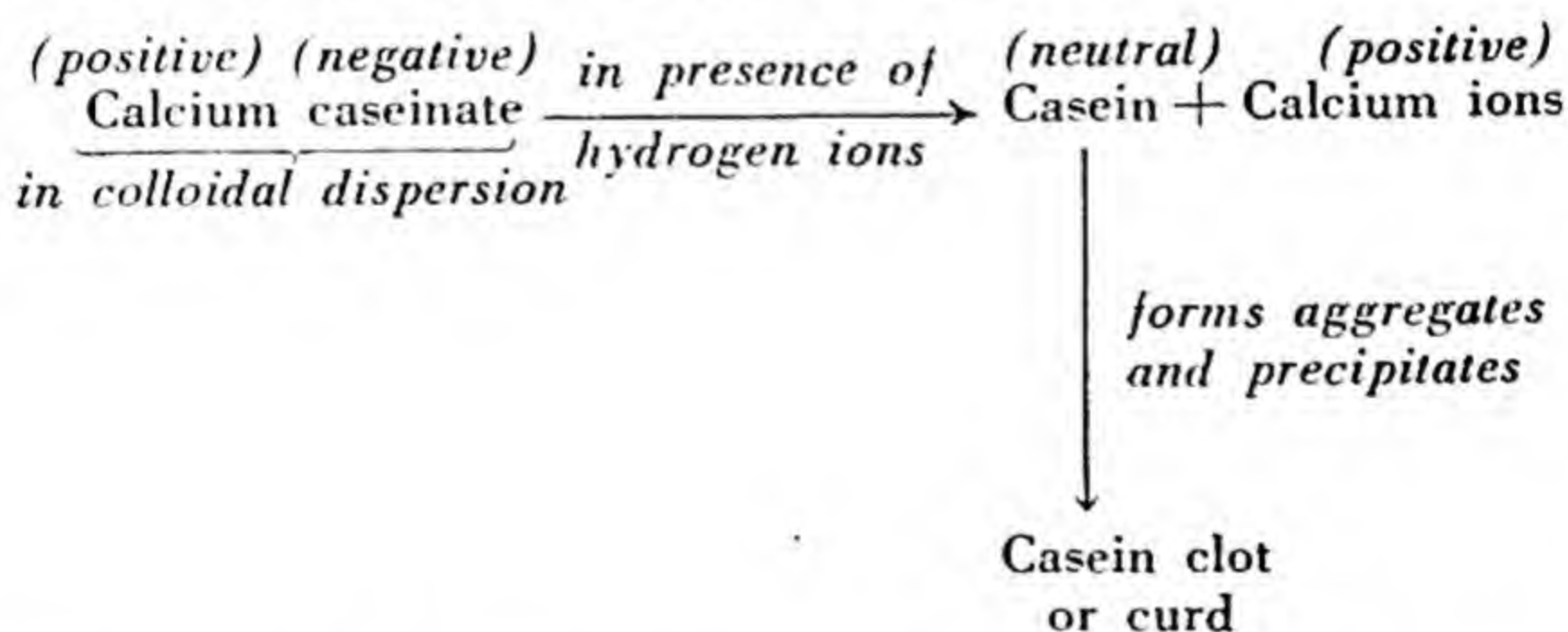
Precipitation with acids. Among the acids that frequently are responsible for the precipitation of casein from milk are lactic acid, which results from bacterial action involving lactose when milk sours, and the acids of tomatoes or lemon juice, that are sometimes introduced into the food mixture.

When milk remains undisturbed during the process of casein coagulation, a more or less continuous clot is formed which is called *clabber*. But when the milk is shaken or stirred the gathering of micelles occurs in numerous small clusters called *curds*, in which case the whole dispersion

takes on a familiar curdled appearance. As curds form, a greenish liquid becomes separated which is called *whey*. Whey, therefore, contains all milk components other than casein.

Theoretical explanation. Casein is believed to be present in milk in the form of calcium caseinate in which the calcium is positively charged while the casein is negatively charged. And the casein parts of dispersed calcium caseinate molecules are believed to be kept from gathering into clusters due to the repulsive effects caused by their like negative charges; or, as the scientist says, the colloidal dispersion of casein is stabilized by the negative charges which it carries.

But when hydrogen ions are either formed in the milk as it sours or are introduced, they neutralize the negative charge on the casein part of the calcium caseinate molecules with these results: (1) the positively charged calcium atoms are released into the solution as calcium ions, and (2) the casein molecules, now neutral, begin to cluster into casein aggregates (p. 368).

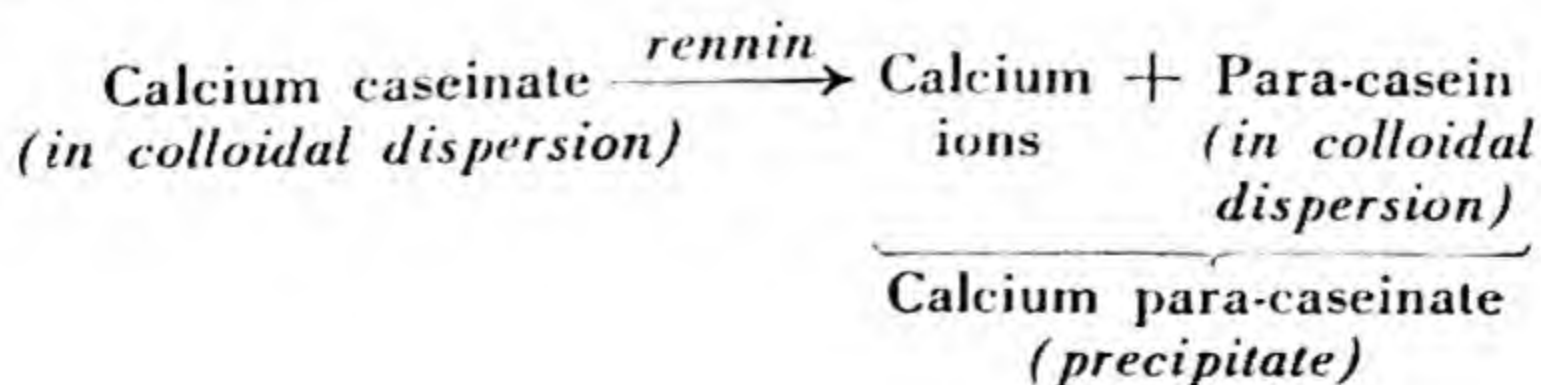


Importance in food concerns. An advantage of the precipitation of casein in this manner is in the making of cottage and other cheeses. In these instances lactic acid is the precipitating agent employed. A disadvantage is encountered in cooking procedures when the careless person or the person unacquainted with appropriate cookery technics, upon bringing milk and acid into contact with each other in the mixture concerned, meets with undesired curdling. The making of cream of tomato soup is one such instance in which hydrogen ions, provided by acid components of the tomato, may be

present in sufficient concentration to cause the casein to precipitate, thus producing a curdled soup. Techniques for lessening this effect are as follows: *First*, the milk can be made into a white sauce, in which case the dispersed, gelatinized starch, by concentrating at the surfaces of colloiddally dispersed casein, hinders the aggregation of the casein micelles. *Second*, the tomato carrying the hydrogen ions can be added to this white sauce, slowly and with constant stirring, thus introducing the precipitating agent in small quantities at a time and distributing it throughout the dispersion, in order to avoid a high concentration of hydrogen ions in any one location. *Finally*, by mixing the white sauce and tomato just before the soup is to be used one lessens the chance of serving an unattractive curdled product.

Precipitation with rennin as agent. *Nature and source of rennin.* As previously mentioned, an agent, other than acids, which causes the precipitation of casein in clot-like form from its colloidal dispersion in milk, is the enzyme *rennin*. This enzyme is formed in the inner lining (mucosa) of the stomach of milk-ingesting animals including humans, sheep, and cows.

Reaction involved. The exact change that is brought about as to calcium caseinate through the agency of rennin is not entirely clear, but it is claimed that in the presence of this enzyme calcium caseinate, which is in colloidal dispersion in the milk, yields up the calcium to become calcium ions while the casein becomes *para*-casein, which also is in colloidal dispersion. However, almost immediately, a combination sets in between the calcium ions and *para*-casein to produce calcium *para*-caseinate, which, being nondispersible, precipitates as a smooth, soft clot.



Casein precipitation by rennin in making desserts. For this use rennin is made from the mucosa of the stomachs of young calves and lambs. This is due to the fact that, since milk is the sole natural food of a young calf or lamb, the gastric mucosa of these animals is especially rich in rennin. This mucosa, after stripping from the rest of the stomach, is processed in such a way as to remove the rennin which, either in a liquid dispersion or in powdered or tablet form, is sold under the name of *rennet*. And when any of these rennet preparations is introduced into milk a palatable, simple, and easily digested dessert is obtained.

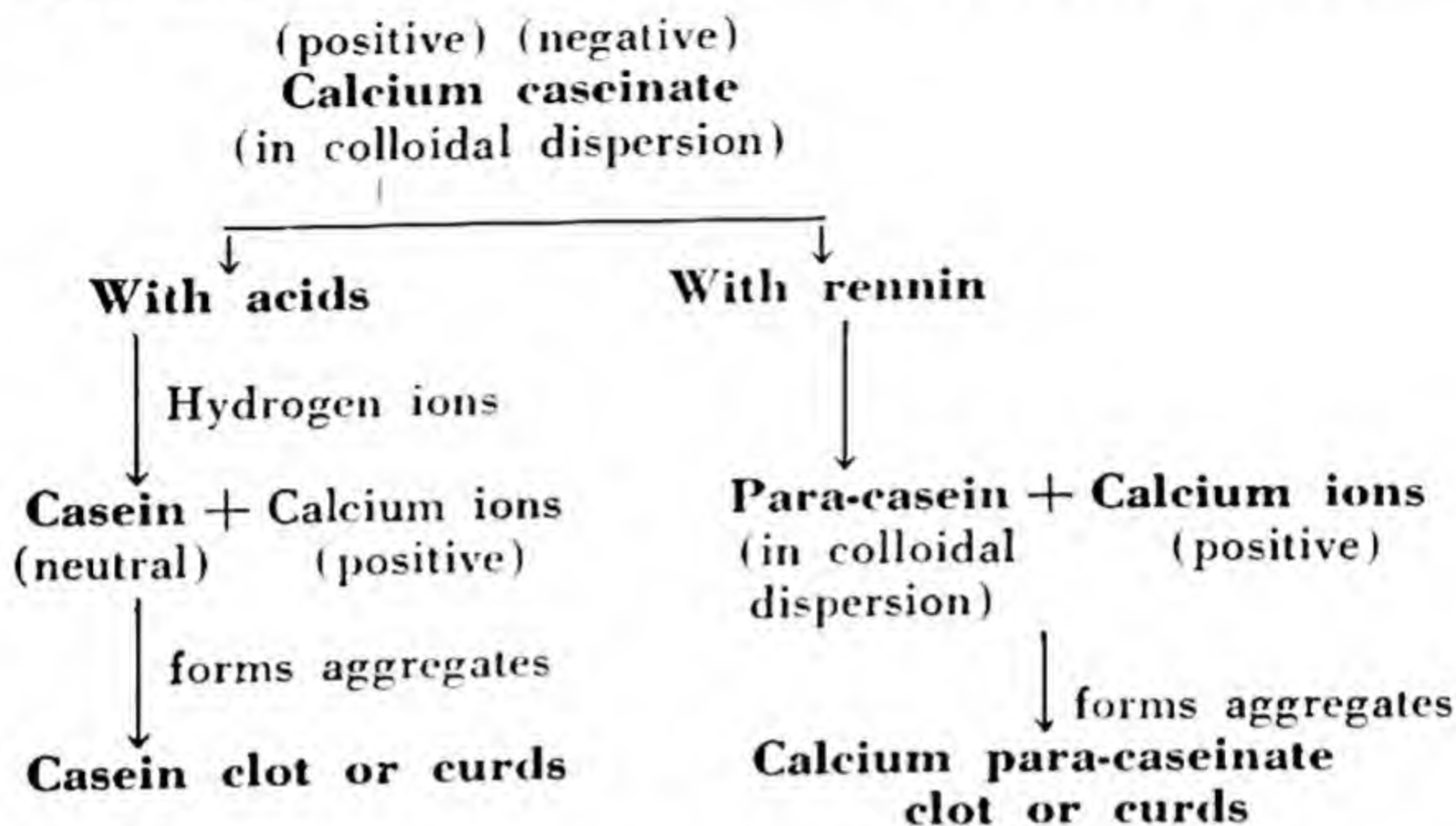
Since rennin is an enzyme, the most favorable temperature range for its action is near body temperature, in this instance within the range of from 104 to 106° F. Accordingly, the usual practice in cookery procedures is to heat the milk to this approximate temperature range, introduce the flavoring, and then quickly stir into this mixture a dispersion of the rennet. The whole dispersion is immediately poured into the dish in which it is to be served and then allowed to stand in a warm place until the clot is formed. The product may then be chilled if desired.

Milk which has been over-heated forms a weaker clot than does raw or pasteurized milk when the same proportion of rennet to milk is used for both. Dried milk with rennet forms a very weak clot. With boiled and evaporated milks, the action of rennet yields only a suggestion of a clot or, in some cases, no clot at all. The reason why the heating, that is necessary for obtaining dried and evaporated milks (pp. 164, 162), impairs the clotting property of casein by rennin is far from clear.

Physiological function of casein precipitation. From a physiological viewpoint, the presence of rennin in the gastric juice is perhaps for the purpose of precipitating casein from ingested milk, at least in part, before it enters the intestine. The digestional advantage that is gained by this preliminary is not understood. However, the chief interest in rennin

in this discussion is in its effect and its usefulness in food preparations.

SUMMARY CHART
ACID AND RENNIN AS CASEIN PRECIPITATING AGENTS



Effect of heat on casein. It should be emphasized that casein of milk is not coagulated by heat within a reasonable time at temperatures ordinarily encountered in cookery. In fact, Rogers⁵ states that it requires all of 12 hours of heating at 212° F., 1 hour at 266° F., and 3 minutes at 302° F. to bring about coagulation of this protein. But when the solids of milk are concentrated as in evaporated milk (p. 162), less heat is required to bring about casein coagulation: in fact only 10 minutes of heating at 266° F. rather than 1 hour at this temperature with whole, fresh milk.

Surface skin on heated milk. When milk is heated for more than a few minutes, even at temperatures well below the boiling point, a thin skin forms over the surface. If this is removed another skin forms, and will do so repeatedly. The exact nature of the skin is not clear, but it is probable

⁵ Rogers, L. A., *Fundamentals of Dairy Science*, 2nd ed. New York: Reinhold Publishing Corporation, 1935, p. 208.

that it is composed of some calcium caseinate, some calcium salts, and fat; it is *not* the result of heat-coagulation of casein. Because evaporation from the surface facilitates skin formation, it follows that when milk is being heated it should be covered. Or, when a food mixture which includes milk is such that it can be beaten during the heating process, the skin formation can be entirely prevented by employing this technic. The reason is that beating causes the formation of a foam which, serving as an effective surface covering, reduces evaporation in this area to a minimum. This procedure can be taken advantage of in the preparation of milk beverages such as cocoa and chocolate.

Lactalbumin. Lactalbumin is a protein component of milk that is present in amounts of less than 1 per cent. It is a simple protein of the albumin class (p. 382) and, like casein, it ranks high among proteins which are biologically complete. Also like casein, lactalbumin is dispersed in milk in colloidal dispersion. It differs from casein, however, in that it is not precipitated either through the agency of rennin or, at ordinary temperatures, by an acid.

Lactalbumin, like all albumins, is heat coagulable. At about 158° F. a flocculent precipitate begins to assemble which gradually settles at the bottom and sides of the container in which the milk is heated. Also, as with all albumins, the presence of an acid facilitates heat-induced precipitation of this milk protein. Obviously, any loss of lactalbumin from the milk dispersion represents a loss in food value which precautionary measures in milk cookery should take pains to avoid. This can be accomplished by heating the milk over hot water instead of over direct heat. If this technic is observed, and if the heating period is kept to a minimum, the precipitating effect on lactalbumin is negligible.

Milk proteins precipitated by tannins and salts. As already stressed, the casein and lactalbumin proteins of milk are affected differently in respect to precipitation when heated or when in contact with acids or with the enzyme rennin.

Both, however, are precipitated by tannins and salts. It follows, therefore, that when milk is heated with foods which contain either tannins or salts in sufficient concentration, the mixture takes on a curdled appearance which in a prepared dish is very unattractive.

Precipitation by tannins. Tannins are components of many vegetables. The frequent curdling of cream of pea and asparagus soups and of scalloped potatoes is attributed to the presence of tannins in these vegetables and their precipitating effect on the proteins of the milk that is used in preparing such food products. Fortunately this curdling effect can be lessened or even completely avoided in these soups by observing the same technics as previously recommended for making cream of tomato soup (p. 147). In preparing scalloped potatoes the use of a thin cream sauce, instead of just milk, to be followed by baking in a slow oven, 300 to 325° F., are effective means of insuring an uncurdled and attractive finished product. In this procedure the gelatinized starch of the white sauce concentrates at the surfaces of the dispersed protein micelles and inhibits their aggregation into curds.

Precipitation by salts. Salts are troublesome as precipitating agents only when present in very high concentration. In the preparation of a creamed dish of highly salted codfish, for example, or in the baking of any highly salted fish or meat in milk, the curdling of milk proteins often takes place. But, according to Lowe,⁶ in a baking procedure, curdling is less likely to occur if only a portion of the milk is added to the meat when cooking is started and the rest of it added, cold and gradually, during the baking period.

CARBOHYDRATE

The carbohydrate of milk is the disaccharide sugar *lactose*. This sugar is much less soluble and much less sweet than sucrose (p. 21). Lactose is not subject to fermentation by

⁶ Lowe, B., *Experimental Cookery*, 3rd ed. New York: John Wiley & Sons, Inc., 1943, p. 322.

bakers' yeast, as is sucrose (p. 25), but it is fermented to yield lactic acid and other substances through the agency of enzymes secreted by various bacteria. Some fermented milks, such as yogurt, are products of this type of fermentation.⁷

The souring of milk is due to the presence of lactose, since lactic acid-forming bacteria, in using lactose as food, make lactic acid as one of the products concerned. The value of this bacterial action is discussed in the section on pasteurized milk (p. 155).

MILK FATS

Amount present. The amount of fats in milk varies from approximately 3.45 per cent in milk from Holstein cows to 4.98 per cent and 5.14 per cent in milks from Guernsey and Jersey cows respectively.⁸

Nature of dispersion. Fats are suspended throughout the milk dispersion in the form of an *emulsion*. The distributed globules vary in size according to the quantity of fat present, globules of largest size appearing in milks of highest fat contents.⁹ Each fat globule is surrounded by a thin film which, although there is not common agreement as to its exact nature, is thought to be largely casein. But whatever the composition of this film, its acts to stabilize, to a large extent, the suspended fat globules in their emulsion dispersion throughout the milk.

Cream layer. Within a milk dispersion there is a tendency for fat globules to assemble into grape-like clumps, a condition which becomes more pronounced at the lower temperatures of around 40 to 45° F. at which milk is usually stored, than at the higher temperatures of its usage. And

⁷ Rogers, L. A., *Fermented Milks*, United States Department of Agriculture, Bulletin No. 319 (1928). Revised by W. R. Albus.

⁸ Eckles, C. H., Combs, W. B., and Macy, H., *Milk and Milk Products*, 3rd ed. New York: McGraw-Hill Book Company, Inc., 1943, p. 46.

⁹ Rogers, L. A., *Fundamentals of Dairy Science*, 2nd ed. New York: Reinhold Publishing Corporation, 1935, p. 71.

both large aggregates of small fat globules and single large fat globules have a greater tendency to rise to the top of milk upon standing than do small individual globules. It follows, therefore, that a better cream layer forms at the top of refrigerated than of unrefrigerated milk.

Homogenized milk. In some cases the rising of fat to the top of the milk is not desired, as, for example, in milk fortified with vitamin D (p. 155). Under such circumstances, the milk is subjected to a process of homogenization. This calls for heating the milk to about 145° F. and forcing it under pressure through very fine orifices. During this treatment, large clumps of fat globules and large single globules become divided into tiny single globules which remain permanently dispersed throughout the milk. Homogenized milk may be used interchangeably with unhomogenized milk in all cookery processes which call for whole milk.

INORGANIC FOODSTUFFS¹⁰

The salt components of milk include potassium, sodium, calcium, and magnesium chlorides and phosphates. These salts are all held in true solution in the water component of the milk with the exception of a small portion of a calcium phosphate, which is present in colloidal dispersion, and the portion of the phosphate which is a constituent of casein (p. 145).

(Of the salts present, heating the milk affects only the colloidally dispersed calcium phosphate, micelles of which have a tendency to aggregate and precipitate when milk is heated. But even this can be largely avoided by observing the same

¹⁰ Materials of plant and animal origin are mixtures of organic compounds, which are composed mainly of carbon, hydrogen, nitrogen, and oxygen, and of inorganic compounds, which include water and salts. When a sample of any such material is heated sufficiently, the water evaporates and the organic compounds are largely converted into gaseous substances which pass off as such. But a solid residue, chiefly a mixture of inorganic oxides, is left behind. This residue is referred to by various expressions such as *ash*, *minerals*, and *inorganic constituents*.

The "ash" from material of plant or animal origin, therefore, is indicative of the inorganic materials, chiefly salts, originally present in the plant or animal.

measures for preventing a precipitation of this salt that are used for preventing precipitation of lactalbumin (p. 150).

From a nutritional viewpoint the most important contributions of milk to mineral requirements of the diet are the elements *calcium* and *phosphorus*, provided within the compounds concerned. In fact, there is experimental evidence to indicate that of all food materials milk is the best single source of calcium both in respect to the amount present and to the readiness with which the body is able, during metabolic processes, to take it from calcium compounds of milk for the making of other calcium compounds that are so essential for body needs.

Mention should also be made of the *iron* content of milk. Although it is true that iron compounds are present in milk in very small amounts, they appear to be, in some way, of extraordinary nutritional value. Sherman states that “. . . milk has a dietary value in the body's economy of iron which in some way extends beyond its iron content.”¹¹

VITAMINS

Milk contains important amounts of vitamin A value (p. 178) and riboflavin, but lesser amounts of thiamine, ascorbic acid, and vitamin D.

The vitamin A value of milk is due both to the yellow pigment carotene, a precursor of vitamin A, which has been transferred into the milk fat from the feed of the cow, and to the presence of vitamin A itself, into which more or less of the carotene has been previously converted in the cow's body. Although carotene is yellow, vitamin A made from it is colorless. Furthermore, there are other yellow pigments besides carotene which are distributed in milk fats. Therefore, while the intensity of the yellow color of milk may possibly carry some significance as to the quantity of carotene present, it cannot be considered an entirely reliable indication of the richness of milk in vitamin A value.

¹¹ Sherman, H. C., *Chemistry of Food and Nutrition*, 7th ed. Copyright, 1946, by The Macmillan Company and used with their permission.

Riboflavin, sometimes called both vitamin B₂ and vitamin G, is the greenish-yellow pigment that remains in the whey of milk after the precipitation of casein. Like carotene and vitamin A, the amount of riboflavin in milk is influenced by the amount previously present in the cow's feed. Light has a destructive effect on this vitamin; therefore milk should never be permitted to stand exposed to light for any length of time.

Thiamine and ascorbic acid are other vitamins which occur in milk, but only to a limited extent. Moreover, the original small amounts of these vitamins are so greatly reduced by the pasteurization process, now generally in use, that milk cannot be relied upon to contribute these two vitamins to the diet in any significant quantities.

The amount of *vitamin D* in milk is small and variable. Like vitamin A and carotene, it occurs dispersed in the milk fat. A recent practice is that of fortifying the milk by increasing its vitamin D content. Several methods are used, such as feeding irradiated foods to the cow, or adding a concentrate of vitamin D to the milk, or direct irradiation of the milk itself with ultraviolet light. Fortified milk is of greatest value in feeding infants and young children for whom vitamin D is a dietary essential. Very often the milk is homogenized (p. 153) in order to make it impossible to remove the cream and with it the vitamin D.

PASTEURIZATION OF MILK

Bacterial action in fresh milk. Milk is a fluid which is warm when drawn from the cow, therefore it presents at once a favorable medium for growth of any microorganisms that may be in it when drawn or that may gain entrance in the course of handling the milk in preparation for personal use or for marketing. It follows that careful handling of the milk necessitates its immediate cooling. But it is now the general practice, especially in cities and large towns, to pasteurize all milk which is sold commercially in order to make it safe from a health viewpoint (p. 157).

Reasons for pasteurization. Specifically, the objects in the pasteurization of milk are: (1) to destroy all disease-causing bacteria, among which are those which cause tuberculosis, typhoid, hoof and mouth disease, and undulant fever; (2) to destroy all bacteria which alter milk proteins. But pasteurization should be accomplished without destroying too many of the acid-forming bacteria in the milk. The survival of these bacteria is advantageous, in that, as the milk stands, they feed on the lactose present to make lactic acid, thereby creating an unfavorable environment for the development of any undesirable types of organisms which may have survived the pasteurization process. The presence of lactic acid, as indicated by change in odor and flavor, is also a warning signal to the cook which tells her that the milk should be used without further delay unless sour milk is desired.

Methods used. Whether or not milk is pasteurized is left entirely to the rulings of the community concerned. Where this protective measure is practiced, it is accomplished by either of two methods called: the flash method and the holding method.

According to the flash method, the milk is heated at a temperature of 160° F., or above, from 30 to 60 seconds. *In the holding method*, the milk is heated to temperatures of from 140 to 145° F., and held there for at least 30 minutes. In both methods, after the heat treatment, the milk is cooled quickly to about 45° F. The exact temperature to which the milk is heated and the holding time are conditions that are subject to local health laws, and these vary in different localities. The holding method is generally preferred over the flash method for the reason that it more nearly accomplishes the specific objects of pasteurization for destruction of bacteria of different types.

Effect upon vitamin content of milk. The pasteurization process does not affect to any significant extent the vitamin A, or the carotene, or the riboflavin content of milk.

It does, however, lower the original amounts of both thiamine and ascorbic acid; but even raw milk cannot be relied upon as a good source of either of these two vitamins.

SANITARY CONTROL OF MILK

In order to encourage high standards of sanitation in regard to milk, its production and distribution, various bureaus¹² of the United States Government have cooperated in formulating standards and control measures which have as their purpose the insuring of a safe milk supply for people throughout areas in which the recommendations become adopted and enforced. These standards and milk control measures are set forth in the so-called *Milk Ordinance and Code*. They are not federally mandatory, but, if so desired, they may be adopted by any state or any community as milk-control legislation within that state or community; and obviously, once these measures become law, all milk distributed within the borders concerned must meet all conditions specified.

A brief summary of these federally recommended milk-control measures follows under the specific headings as they appear in the *Milk Ordinance and Code*.¹³

Definitions. To begin with, and in order to circumvent any possibility of substitution, misunderstanding, or error, the *specific foods that come under the control measures*—namely, milk and certain milk products—are defined. The treatment which can be accepted as *pasteurization* is also defined, as is the legal position as to what constitutes milk *adulteration*.

It is interesting to note that the milk products which fall under the specified control measures are: cream, homo-

¹² United States Public Health Service, Division of the Federal Security Agency, in cooperation with the Bureau of Dairy Industry of the United States Department of Agriculture.

¹³ These milk-control measures are covered at length in Public Health Bulletin No. 220, Federal Security Agency, United States Public Health Service, Washington, D. C.

genized milk, vitamin D milk, buttermilk, skimmed milk, milk beverages, and goat's milk. Not included are: evaporated milk, condensed milk, dry milk, and cheese.

Inspection of dairy farms and milk plants. This section of the ordinance provides for frequent inspections of dairy farms and milk plants by local health officers in order to discover any possible violations in the observance of sanitary control measures.

Examination of cows. This measure involves periodical testing of cows by licensed veterinarians for certain diseases such as tuberculosis and undulant fever.

Examination of milk. It is required that an examination of milk be made by local health officers, which shall include periodic examination both of milk produced at the dairy farm and that collected at the milk plant. It is also required that milk in stores, restaurants, and other public eating places shall be examined by these officials as often as is deemed necessary.

Grading of milk. People in general are acquainted with the fact that in many localities the milk is distributed under different grades. But it is quite probable that very few people are informed in regard to the basis upon which these grades are determined; indeed, there are those who think that the difference in milk grades lies in the quantity of cream contained. This is definitely not the case.

Actually, the criteria for grading milk, as laid down by the *Milk Ordinance and Code* are on the basis of: (1) the bacterial count per given volume of the milk as determined by laboratory investigation, and (2) whether the milk comes from dairy farms which meet with designated requirements. The following deals with grades of milk thus established together with conditions which they must meet:

Terms applied to grades of milk

Certified milk	.....	raw	or	.....	pasteurized
Grade A milk	.....	raw	or	.....	pasteurized
Grade B milk	.....	raw	or	.....	pasteurized
Grade C milk	.....	raw	or	.....	pasteurized

Certified milk is milk which conforms to the requirements of the *American Association of Medical Milk Commission* and is produced under the supervision of the state or local board of health. It may be either raw or pasteurized. Such milk is the highest quality of milk obtainable and is often used for infant feeding.

Grade A raw milk must not exceed the limit of bacterial count permitted and it must meet the highest standards as to sanitary production. ***Grade A pasteurized milk*** must be of similar quality with these differences: before pasteurization, the bacterial count may be higher than for raw milk of this grade; but, after pasteurization, it must be lower for grade A pasteurized than for grade A raw milk.

Grade B milks, raw and pasteurized, fall below the standards set for raw and pasteurized milk of grade A quality, but they must nonetheless meet definitely specified criteria, both as to the limit of bacterial load and as to sanitary conditions of production that are permitted for milks of these grades.

Grade C milks, raw and pasteurized, are products which violate the requirements for grade B products, raw or pasteurized. Such milk should be used only for cookery purposes; this is especially true of the grade C raw milk.

Need for more widespread milk control. As stated above, the use of the *Milk Ordinance and Code* by states or local communities is optional, but when adopted it becomes mandatory that all of its provisions be observed "without downward revisions, or changes in grade names, or significant changes in the form of the ordinance."

In populated areas where this ordinance has not been adopted, it is imperative that similar legislation be passed and enforced for the production and distribution of a safe milk supply to the people of the communities concerned.

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CHAPTER XIII

MILK PRODUCTS—CHEESE

MILK PRODUCTS

Cream. Commonly, the term “cream” is applied to the fat-rich layer which rises to the top of whole milk upon standing. But officially, and more exactly, the term “cream” applies to a milk product which has a fat content that ranges from approximately 18 to 40 per cent.

Formerly, for the purpose of separating the cream for making butter or for other uses, the milk was put into shallow pans in the farm dairy and allowed to stand for from 1 to several days, during which time the fat globules rose slowly to the top of the milk and were eventually skimmed off. In this method for separating cream, considerable fat was left distributed in the skim milk. But in the dairy industry today, cream is removed from whole milk by means of a “cream separator,” and the method involved is more efficient and more speedy; also the mechanism of the separator can be so adjusted that cream of any desired percentage of fat content can be obtained.

Cream is designated as to type on the basis of fat content as follows: *light or coffee cream* containing 18 to 20 per cent fat; *medium cream* containing from 30 to 36 per cent fat; and *heavy cream* containing, usually, from 36 to 40 per cent fat.

Whipped cream. This milk product is an air-in-water foam (p. 371) in which fat globules are piled up in the films of liquid which surround the dispersed air bubbles (Fig. 9). Because of their presence in these films, the fat globules exert

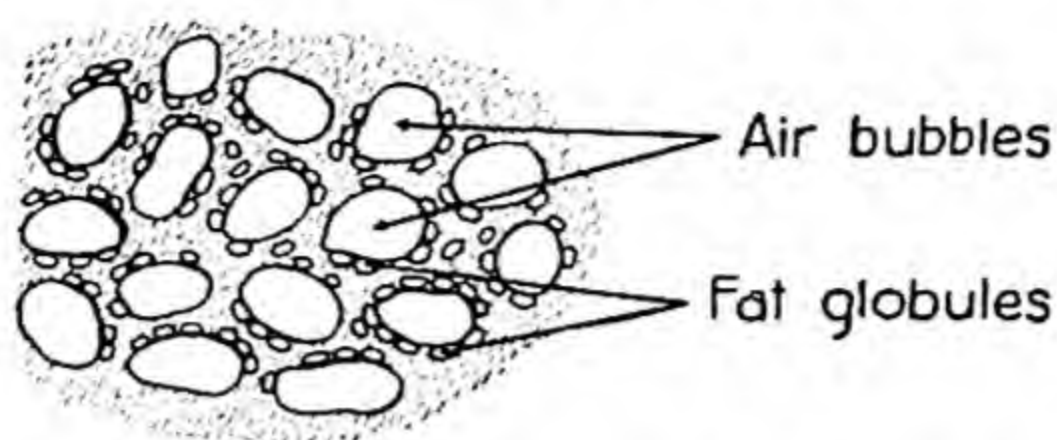


Fig. 9. Diagram suggesting a cross section of mass of whipped cream.

a stabilizing influence on the gaseous dispersion to prevent coalescence of air bubbles; indeed, frequently they tend to make the whipped cream mass so stable that the foam is able to persist for many hours.

Uses in food preparations. In cookery concerns, whipped cream has many uses. It may be incorporated into food mixtures to make attractive salads and desserts, or it may be used as a garnish for various types of dishes. In all of these uses, certain qualities are desirable: the cream should whip to a large volume; the whipped mass should be stiff yet fluffy; and, finally, it should not show any drainage of liquid as it stands. These are qualities which are best obtained by whipping cream containing about 30 to 35 per cent fat. If the fat content is less than 30 per cent, the whipped product lacks stiffness and shows excessive drainage of the liquid; if it is much above 35 per cent, the volume obtained upon whipping is lessened and the foam is so stiff that it is heavy, compact, and without the desirable fluffy quality. But no matter what the fat content, cream whips more easily if it is at least 4 hours old and has been thoroughly chilled to temperatures of around 40° F. After the cream is whipped it should be kept chilled until needed for use.

Evaporated milk. How obtained. Evaporated milk is milk from which about 60 per cent of the water has been removed; the product is then sterilized in sealed cans. The removal of water is accomplished by heating the milk in such a high vacuum that it will boil at temperatures of from 130 to 150° F., thus effecting an evaporation of water without

scorching the milk or altering its components to any great extent. The concentrated product is homogenized in order to break up the dispersed fat into such small globules that a cream layer will not form; this product is then placed in cans, sealed, and sterilized at temperatures of from 240 to 245° F. for 15 minutes.

At the present time, a large proportion of evaporated milk is *fortified with vitamin D* either by direct irradiation of the milk with ultraviolet light during its manufacture, or by adding a concentrate of this vitamin before the product is sealed and sterilized.

Since evaporated milk has been sterilized in sealed cans, it will keep for long periods of time; it is, therefore, a convenient form of milk to have on hand against an emergency need. Obviously, after the can is once opened any milk that is not used immediately must be stored in a refrigerator.

Cookery use. When evaporated milk is used in cookery, unless otherwise specified, it should be diluted with an equal quantity of water. It may then be substituted for fresh milk in almost any food product with the exception of those which are mild in flavor, in which case the unusual taste imparted by this milk product may prove objectionable to some people. Evaporated milk cannot be used in the preparation of desserts that require coagulation of casein with rennin as precipitating agent, since the function of rennin is somewhat impaired in this milk product.

Condensed milk. This is another milk product which, like evaporated milk, is concentrated; but it differs from evaporated milk in that sugar has been added to give a final product that contains about 40 per cent carbohydrate. This added sugar may be either sucrose, or dextrose, or a mixture of these two sugars. Because of the high sugar content, condensed milk is not sterilized during manufacture as is evaporated milk, but owes its excellent keeping quality to the inhibiting effect of sugar on the activities of microorganisms. However, during the processing and prior to the evaporation

of water, the milk is heated to a temperature of about 170° F. in order to destroy some bacteria and to inactivate any enzymes present in the milk, which, if allowed to remain, would cause undesirable changes in some milk components during storage.

Owing to the high sugar concentration, condensed milk cannot be used advantageously for as many cookery uses as can evaporated milk.

Dry milk. *Two varieties.* Dry milk is milk from which most of the water has been removed, leaving a fine, creamy-white powder. There are two varieties of dry milk products: (1) fresh whole milk is dried to give *dried whole milk*; or (2) fat is removed from fresh milk, after which the water is evaporated by drying; this product is called either *dried skim milk* or *non-fat dry milk solids*, the latter name being the one that is preferred in the industries in which this product is used.

Methods of manufacture. Irrespective of the type of dry milk that is being produced, there are two general methods for removal of water,¹ called the *spray process* and the *roller process*.

In the spray process, fresh milk is sprayed, under high pressure, into a drying chamber where it comes into contact with a current of filtered dry air which causes a rapid evaporation of water. The dried solids settle to the bottom of the chamber in the form of fine particles.

In the roller process, the fresh milk is spread by mechanical means in a thin film over the surfaces of hot, revolving metal rolls. The water evaporates and milk solids are left on the rolls in thin sheets which are scraped off by knife blades. Later these solids are ground to a powder and screened to make uniformly sized particles. A modification of this method is that of enclosing the rolls in a vacuum cham-

¹ *Dry Milk Solids*, American Dry Milk Institute, Inc., Chicago, Bulletin No. 904 (1942).

ber which permits evaporation of water from the milk at a lower temperature.

If dried skim milk is held in a cool, dry place it will keep for a long while. Dried whole milk does not keep so well because of the fat, which tends to become rancid. Like evaporated milk, these dried milk products constitute an always available supply of this essential food.

' Uses in cookery. In order to reconstitute dry milks to approximate whole milk, as nearly as is possible, water is added in the following proportions:

1 cupful (4½ oz.) of dried whole milk or	} to 3¾ cupfuls of water
7/8 cupful (3½ oz.) of dried skim milk	

For either type of dry milk the reconstitution can be accomplished in the following ways:

1. The dry milk can be sprinkled on the surface of the water and allowed to stand thus for several minutes, after which the mixture should be beaten vigorously with a rotary beater.

2. The powder can be placed in a bowl, moistened and stirred to a smooth paste with a little water, the mixture can then be diluted with the remaining required amount of water.

Dry milks can be used in cookery either as reconstituted or in the dry form depending upon the product at issue. If the product necessitates fluid milk—such as cream soups, cocoa, or custards—the reconstituted milk must be used to replace fresh milk as called for in the recipe. But if the product is a flour mixture—cake, biscuits, etc.—it is more convenient to use the dry milk as such. In this instance the dry milk should be sifted with the other dry ingredients, and a volume of water equal to that of the milk specified in the recipe introduced.

Food value of evaporated and dried milks.² Evaporated milk and dried whole milk, when reconstituted for use,

² Henry, K. M., Houston, J., Kon, S. K., and Osborne, L. W., "The effect of commercial drying and evaporation on the nutritive properties of milk," *Journal*

are comparable to fresh milk in respect to riboflavin and vitamin A value. Some loss of thiamine is incurred in the drying of milk but this loss is apparently considerably less than that which takes place when milk is evaporated; therefore reconstituted dried milk may be considered superior to evaporated milk in thiamine content. The same condition holds for ascorbic acid, which is retained to a greater extent in dried milk than in the evaporated product. In considering the relative food value of dried and evaporated milks, it should be kept in mind, however, that even fresh milk is not included among food materials that supply thiamine and ascorbic acid in large amounts.

CHEESE

The various cheeses, as ancient and valued foods of man, have throughout past centuries been made from the milk of different kinds of animals. Moreover, the names of some of the cheeses that are so familiar today are derived from the towns or countries in the old world where the particular products were first made.

And this liking for cheese has come to be shared by people, the country over, in the United States. As a consequence, it is not surprising that, during the passing years, processes for manufacturing different varieties of this milk product have been developed within the United States itself, with the result that enormous quantities are now made here annually. Hence it is no longer necessary for people in this country to rely entirely upon England for Cheddar cheese, upon France for Camembert cheese, upon Switzerland for Swiss cheese, and so on.

The making of cheese. Cheese can be defined as the casein of milk, together with more or less milk fat and varying amounts of whey.

of Dairy Research, Vol. 10 (1939), pp. 272-293.

Kon, S. K., "Biennial reviews of dairy science. Nutritional value of milk and milk products," *Journal of Dairy Research*, Vol. 11 (1940), pp. 196-224.

Stewart, A. P., Jr., and Sharp, P. F., "Vitamin C content of market milk and powdered whole milk," *Journal of Nutrition*, Vol. 31 (1946), pp. 161-173.

The particular variety of cheese depends upon several factors which include: the source of the milk—from cow, or sheep, or goat; whether the cheese requires the use of whole or skim milk; the agent used to precipitate the casein from colloidal dispersion in the milk—whether acid or rennin (p. 149); and the subsequent treatment and final curing process.

With acid as precipitating agent. If the precipitating agent for casein is lactic acid, either this acid is allowed to develop naturally as the milk sours, or a lactic acid starter is introduced. In home-made cottage cheese this acid is relied upon entirely to cause the coagulation of the casein. In such cheese the curd is separated from the whey by draining and squeezing, after which the resulting curd is seasoned as desired.

With rennin as precipitating agent. If the milk casein is precipitated through the agency of the enzyme rennin, the milk should be slightly acidified. Most commercial cheese-making processes use this as the most efficient means for effecting the desired end. Provided whole milk is used, as casein coagulates it entraps fat globules within the mesh of the coagulum.

In commercial practice the coagulated mass is called *curd*, which, after it has been treated in various ways, is separated from the whey by means of a press, more or less completely, depending upon whether a hard or soft cheese product is desired. Finally, the curd is pressed into the shape that has come to be characteristic of the particular cheese; and the mass—now *green* or *uncured* cheese—is ready for the ripening or curing procedure.

The curing process. During the curing process, which may extend anywhere from several months to several years, controlled changes are brought about which are peculiar to a given variety of cheese. These changes are effected by activities of enzymes or specific microorganisms—molds or bacteria—and the products so obtained contribute their own characteristic flavor, texture, and consistency to the cheeses respectively concerned.

As ripening progresses a rind forms on the surface of the cheese which acts as a protective coating to prevent the product from drying out.

Classification. Cheeses are classified as soft or hard depending chiefly upon the proportion of water which is present in the finished product. Soft cheeses are classed as unripened and ripened—the former should not be kept for long before using. All hard cheeses are ripened. Finally, all ripened cheeses—both soft and hard—are classed as to whether the ripening involves activities of molds or of bacteria. Outstanding types of cheeses, according to this classification, are listed in the accompanying table.

CLASSIFICATION OF CHEESE ³

Soft cheeses, moisture 40–75%		Hard cheeses, moisture 30–40%	
Unripened Cottage Cream Neufchâtel		Semihard	Very hard
Ripened <i>By molds</i> Camembert Brie		Ripened <i>By molds</i> Gorgonzola Roquefort Stilton	Without gas bubbles Cheddar Edam Gouda
<i>By bacteria</i> Limberger Liederkrantz		<i>By bacteria</i> Brick Münster	With gas bubbles Emmenthal Swiss Parmesan

Processed cheese. Processed cheeses, also called pasteurized cheeses, are products of recent manufacture, many varieties of which are found on the market today in foil-wrapped loaves or in small packages or glass jars of various sizes.

To make a processed cheese, experts select several lots of

³ Rogers, L. A., *Fundamentals of Dairy Science*, 2nd ed. New York: Reinhold Publishing Corporation, 1935, p. 235.

a specific variety and blend them in proportions that will produce the particular kind of finished product that is desired. Less than one per cent of an emulsifying agent, such as sodium phosphate or sodium citrate, is added in order to maintain the desired consistency. Then the cheese mixture is shredded, pasteurized, and packed in airtight packages.

Processed cheeses provide a great variety of flavors; they have excellent spreading and cooking qualities, and have no wasteful rinds—all of which conditions contribute to their popularity.

Foodstuffs provided in cheese. (See Fig. 10.) As a highly concentrated milk product, any cheese is a food material which is *rich in protein*. Most cheeses also contain *considerable quantities of fat*, and all contain *some carbohydrate* (lactose). According to Sherman,⁴ the quantities of these foodstuffs in several representative varieties of cheese (American Cheddar, Parmesan, Swiss) are as follows:

Protein	19.2 to 36.3%
Fat	27.4 to 33.2%
Carbohydrate (lactose)	1.4 to 2.3%

Since cottage cheese is made from skim milk and, as a very soft cheese, contains considerable whey, it is relatively low in fat content (0.8%) but relatively high in lactose (4.3%).

In respect to *mineral constituents* (p. 153), all cheeses contribute significant amounts of phosphorus and, with the exception of cottage cheese, of calcium. The considerable difference between calcium-contributing compounds in cottage and other cheeses is owing to the fact that the curd of cottage cheese is chiefly precipitated casein (not calcium caseinate), since most calcium remains behind as calcium ions, thereby contributing to soluble calcium salts in the whey. But the curd of other cheeses—that is, those formed by casein coagulation

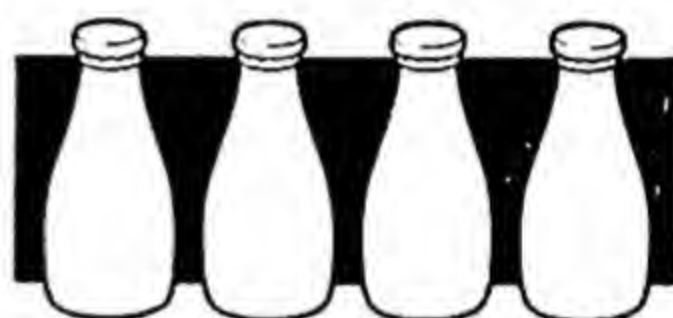
⁴ Sherman, H. C., *Chemistry of Food and Nutrition*, 7th ed. New York: The Macmillan Company, 1946, p. 622.

ONE POUND OF CHEESE* NATURAL OR PROCESS

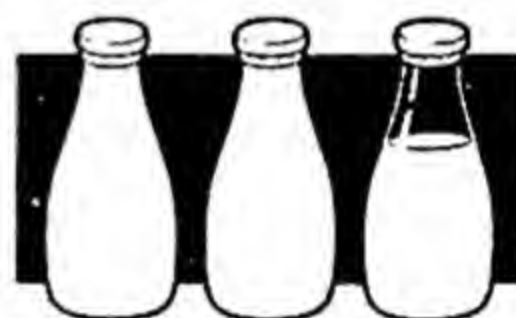


CONTAINS THE EQUIVALENT OF

4 QUARTS OF MILK IN
MILK FAT



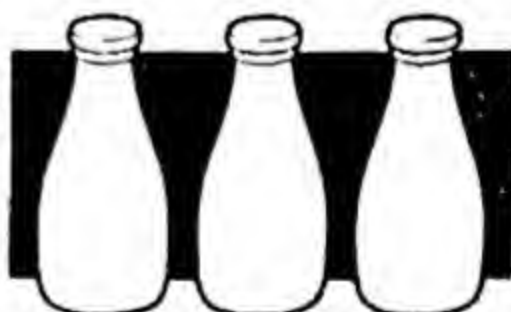
24/5 QUARTS OF MILK IN
MILK PROTEIN



3 1/5 QUARTS OF MILK IN
MILK CALCIUM



3 QUARTS OF MILK IN
MILK PHOSPHORUS



Both Cheese and Milk are Good Food Sources of **VITAMINS A and G**

*NOTE • BASED ON AVERAGE COMPOSITION OF "MARKET MILK" AND AVERAGE COMPOSITION OF PROCESS AND NATURAL AMERICAN CHEDDAR CHEESE

★ CONSUMER SERVICE DEPARTMENT • KRAFT FOODS COMPANY ★

(Courtesy of Kraft Foods Company.)

Fig. 10.

with rennin as agent—is calcium para-caseinate, hence considerable of the milk's calcium, combined within this compound, is carried down with the coagulum. (p. 147.)

As for *vitamins*, all varieties of cheeses that are made from whole milk are high in vitamin A value. This must be the case since fat globules, becoming entrapped in the curd, remain mixed with the precipitated mass when the whey is drained from it; and both vitamin A and carotene remain dissolved in this fat. At the same time, some whey, which contains important amounts of riboflavin and some thiamine, is also retained. But all cheeses are practically devoid of ascorbic acid.

Cheese, uses and cookery. In the preparation of food dishes, cheese, either raw or melted, can be used in various ways. It is well adapted to use as a spread on crackers or bread. It contributes flavor to sauces to be served with fish, eggs, vegetables, or made-dishes such as timbales. Or cheese can be used as one of the main ingredients in such products as cheese custards, timbales or soufflés, which, because of the richness of cheese in protein, often replace meat in menus.

In all of these uses, except when used raw, cheese should be of such a character that, when subjected to mild heat, it will melt to a soft, tender mass which will blend evenly with other ingredients. On the other hand, it should not, as sometimes happens, become tough or rubbery, form long tough strings, or exude fat.

Cheeses of the several varieties, and even different cheeses of the same variety, show these characteristics to different extents. But, in general, heating the cheese at relatively low temperatures is the advised procedure. Thus, in the preparation of a cheese sauce, one should use a double boiler and keep the water in the lower part below the simmering temperature; or if a cheese dish such as a soufflé is being prepared, one should bake the mixture at oven temperatures which do not exceed from 300 to 325° F.

An interesting study ⁶ of recent date, which pertains to the cooking qualities of Cheddar cheese, has found that a Cheddar cheese with normal, not low, fat content and with high moisture content, also one which has undergone the ripening process for at least six months, lends itself most satisfactorily to cooking uses.

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⁶ Personius, C., Boardman, E., and Ausherman, A. R., "Some factors affecting the behavior of Cheddar cheese in cooking," *Food Research*, Vol. 9 (1944), pp. 304-311.

CHAPTER XIV

EGGS

Production areas. The importance of hens' eggs as food for man is remarkably emphasized by the finding that, during the year 1944, 63,660 million eggs were produced in the United States, which, in terms of consumption, meant 352 eggs per capita of civilian population during that year.

Eggs are produced on farms throughout all rural areas of this country. About half the total production is centered in the North Central states, among which Iowa takes leading place, followed by Minnesota, while the South Central and North Atlantic states rank second and third respectively as egg-producing areas.¹ In addition to these regions, Texas and California, as individual states, also contribute largely to the total egg production¹ of the country.

Structure. (In general, the interior contents of every egg—yolk and white—are differentiated in a well-defined structural arrangement.) And, from a cookery viewpoint, this is a feature of distinct importance since, (in the preparation of various dishes, the white and yolk sections of the egg can be separated easily and almost completely one from the other, thereby increasing the variety of uses for which eggs are suited.)

But it is a well-known fact that the quality of eggs, hence their desirability for cookery uses, is affected by changes that begin to take place in their contents as soon as the eggs are

¹ *Agricultural Statistics*, United States Department of Agriculture, 1946, Table 555.

laid (p. 179); and these changes are reflected in structural features. (Fig. 11.)

The shell. The natural covering for the egg contents, namely, the eggshell, is composed chiefly of the insoluble salt, calcium carbonate, in mixture with smaller amounts of magnesium carbonate, calcium and magnesium phosphates, and

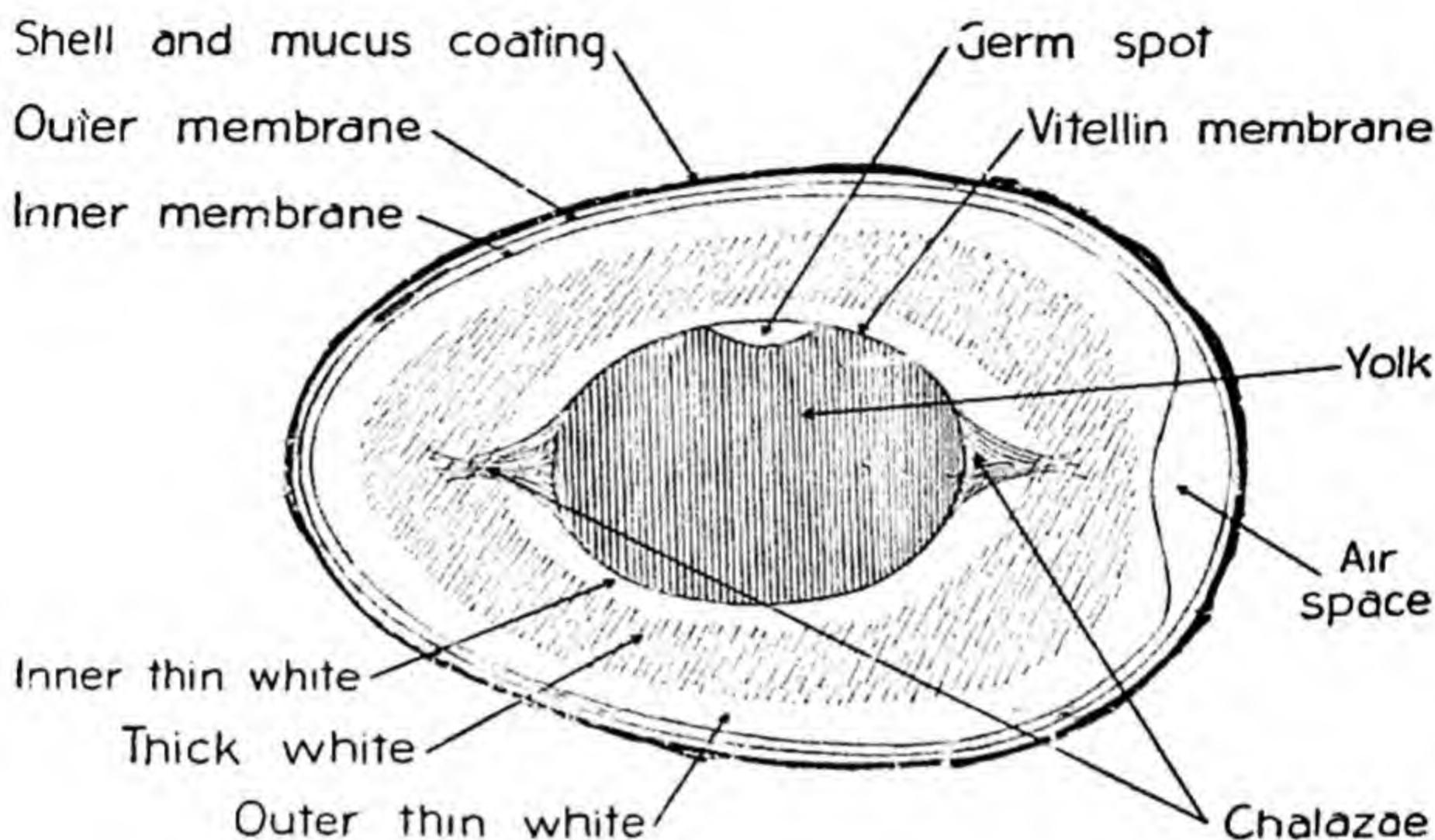


Fig. 11. Diagram indicating structure of an egg.

certain organic compounds. The shell itself is porous, but in the newly laid egg it is supplied with a coating of mucus-like, gelatinous material which tends to seal the pores temporarily; it is by this means that the passage of gases into and out from the egg contents is prevented to some extent. As the egg ages, this material dries out and its sealing effectiveness is decreased.

Lining membranes. Directly within the shell and lining it are two membranes which lie close together, except for a small area at the larger end of the egg where there is an air space between the membranes. This air space is caused by the shrinking of egg contents as they cool from body temperature

of the hen, at the time the egg is laid, to the lower temperature of the surrounding atmosphere.

Egg white. (The egg white, which lies between the inner membrane and the egg yolk, constitutes about 63 per cent by weight of the total egg contents. It consists of three layers or portions: an outer portion of *thin egg white*; next, and quite distinct from the latter, the portion of the egg white which is *thick and jelly-like*; finally, another *thin portion* of white which surrounds the yolk.) In the broken-out egg, the two outer layers of white are easily distinguished, but the inner thin white is obscured by the thick white which surrounds it. The relative proportions of thick and thin whites vary among eggs, but in general they are present in about equal amounts.)

The yolk. The central part of the egg is the yolk. The yolk is surrounded by a covering called the *vitellin membrane*, and it is held in place by two cord-like extensions of this membrane called *chalazae*, which are anchored in the thick portion of the egg white) (Fig. 11).

Components and nutritive value of hens' eggs. The following table presents figures for the composition, in terms of nutrients, of whole broken-out egg, of egg white, and of egg yolk. (The percentages given represent average values, since eggs as produced by different hens differ in amounts of nutrients, depending upon various factors chief among which is the feed employed.)

It will be noted that the distribution of nutrients in egg white and egg yolk is markedly different, a fact which accounts for the well-known difference in their respective nutritive values. It is because of this variation that these two structural parts of the egg will be discussed individually.

Of egg white. The principal solid nutrients of egg white are *proteins*—albumins, a globulin, and mucins: albumins, among which ovalbumin predominates, are present in largest amounts; ovomucin predominates among the mucins. The albumins and the globulin are uniformly distributed through-

PERCENTAGE COMPOSITION OF EGGS

Com- ponents	Whole egg	Egg white	Egg yolk
Water	73.7%	87.8%	49.0%
Proteins	13.4%	Albumins Ovoglobulin } 10.0% Mucins }	Phospho- proteins, } 16.7% chiefly Ovovitellin }
Fats	10.5%	0.05%	Fats 31.6% Fat-like substances Lecithin Cholesterol
Inorganic constituents of various salts and organic compounds	1.0%	Sodium, potas- sium, magne- sium, calcium chlorides (chiefly) and phosphates } 0.82%	Calcium, potas- sium, sodium, magnesium, phosphates (chiefly) and chlorides } 1.5%
Iron, com- bined in organic compounds		0.0001%	0.0087%
Vitamins		Riboflavin	Riboflavin Vitamins A and D Thiamine

out the egg white; they are simple proteins (p. 382) which give colloidal dispersions in dilute salt solutions, and they are readily coagulated by heat. Ovomucin is a protein-carbohydrate complex which is viscous and slippery; it is probably responsible for the jelly-like character of thick egg white, in which it is present in higher concentration than in the thinner

and more watery layers.) As is indicated in the table, egg white contains *very little of mineral salts*, only *traces of fat*, only a *trace of iron* compound, and the vitamin *riboflavin*.

It follows, therefore, that the nutritive value of egg white lies almost entirely in its protein components. But these proteins have high biological value in that they contain all of the essential amino acids, meaning amino acids which, known to be indispensable building blocks for growth and repair of body tissues, must be provided in the food. (p. 136.)

✓ **Of egg yolk.** Chief among the considerable quantity of *proteins* present in egg yolk is the protein called ovovitellin. This is a protein-phosphoric acid complex which is classed as a phosphoprotein (p. 383) and resembles casein of milk in character. It will be observed (see table) that about $\frac{1}{3}$ of the yolk is *fat*, a mixture of several fats, in fact. Associated with these fats are the *fat-like substances* lecithin, which is a fat-phosphoric acid complex (p. 380), and cholesterol (p. 381). From a nutritional angle, the proteins of egg yolk are excellent ones. Ovovitellin (a protein) and lecithin (a fat-like substance) are important sources of phosphorus for the making of various phosphorus compounds that are essential to body needs. The fats are present in finely dispersed, 'emulsified' condition, which renders them available for speedy digestion and absorption.

Egg yolk is much richer than egg white in *mineral salts*; some of these salts are other sources of phosphorus, some are sources of the metal radicals sodium, potassium, calcium, and magnesium, and all contribute to the making of compounds that are of vital significance in human nutrition. Of considerable importance is the fact that egg yolk is one of the few sources, in foods habitual to man, of the element *iron*; and iron, although required in very small quantities for body needs, is nonetheless nutritionally essential.

As for *vitamins*, it will be observed that the yolk of the egg contains not only riboflavin, which is also present in egg white, but important amounts of vitamin A and vitamin D,

as well as appreciable amounts of thiamine. However, it is found that the amounts of all vitamins present in egg yolk, as is true also of riboflavin in egg white, vary among eggs; furthermore, it has been demonstrated conclusively that the quantities of vitamin A, vitamin D, and riboflavin are influenced favorably by including relatively high levels of these vitamins in the diet of the hen.)

Incidentally, some people have a tendency to relate the "vitamin A value"² of egg yolk to the intensity of its yellow color. This is due to the fact that certain of the yellow carotinoid pigments, namely carotenes and cryptoxanthin, are precursors of vitamin A, and these pigments are converted into vitamin A during metabolic processes in the human body. But in the case of eggs, dependence upon yellowness of the yolk as a basis for judging its "vitamin A value" should not be relied upon, both because the predominating yellow pigment of egg yolk is xanthophyll, which is *not* a vitamin A precursor, and because varying amounts of carotene and cryptoxanthin have already been converted into colorless vitamin A by the hen.

Characteristics of fresh eggs. (See Fig. 12, p. 188.)

The *shell* of an egg may be either brown or white in color depending upon the breed of hen producing it. But, irrespective of color, the *shell* of a fresh egg always has a delicate velvety appearance, called "bloom," that is due to the protective mucous coating with which the shell is supplied when the egg is laid. The inner *air cell* of a fresh egg is small. The egg contents when broken-out from the shell show an up-standing, well-rounded *yolk* covered with a clinging layer of *thick egg white*, which, in turn, is surrounded by a relatively smaller amount of *thin egg white*. The yolk may be either golden or light yellow in color, depending upon the amount of carotenoid pigments contained in it, and the white is practically colorless or possibly slightly opalescent.) There is

² "Vitamin A value" of a food includes not only the actual quantity of vitamin A that is already present in the food mass, but also the quantity of those carotinoid pigments (p. 237) present which, as precursors of vitamin A, are converted into this vitamin after the food is ingested by the animal concerned.

no odor other than that characteristic of egg, and upon being put to food use the flavor will be excellent.

Deterioration of eggs. (See Fig. 12, p. 188.) As soon as the egg is laid, changes begin to take place which, if not checked by suitable storage conditions, result in undesirable deterioration. An account of these changes and their effects follows:

As shown in the shell. With deterioration, the mucous protective covering of the shell soon disappears, leaving the shell shiny and more porous, so that moisture and carbon dioxide can more easily pass through it from the egg contents. This causes a loss in weight of the egg, a contraction of egg contents, and a resulting enlargement of the air space between the two membranous linings of the shell.

As shown in the egg white. Accompanying the loss of carbon dioxide through the shell, the reaction of the egg contents, especially of the egg white, changes from nearly neutral in the fresh white, to alkaline, becoming progressively more alkaline as the egg ages. It should be said, however, that factors other than the loss of carbon dioxide may be responsible for the increase in this alkalinity.

As egg deterioration progresses, the thick white gradually loses its firm, jelly-like consistency and decreases in amount, while the volume of thin egg white increases. These changes continue until the entire white portion becomes watery and drains away from the yolk when the egg is broken-out of the shell. The cause of this change in thick egg white is not at the present time entirely clear, although various reasons have been advanced to account for it.

As shown in the egg yolk. Also upon aging, the yolk of the egg becomes more liquid and enlarges as water passes into it from the white through the enveloping vitellin membrane. As a result, the increasing volume of the yolk stretches the enclosing membrane thus weakening it sufficiently so that, in the broken-out egg, the yolk is no longer upstanding and well-rounded, but instead becomes wide and flat. In-

deed, with continued aging, the membrane which encloses the yolk may become so weakened that it breaks when the egg is opened, and, as a consequence, the white and yolk cannot be separated from each other.)

As shown by substances with off-odors. Finally, in aging eggs, certain chemical reactions occur among various egg components which yield compounds that impart characteristic and familiar off-odors and flavors; and if these reactions continue long enough, such eggs become inedible.

Among the compounds that are made from these reactions is the foul-smelling, gaseous substance, hydrogen sulfide. When eggs are heated for some time, as in hard-cooking them in the shell, this gas, made chiefly in egg white, passes through the vitellin membrane and reacts with iron compounds in outer yolk areas to form ferrous sulfide, which can be seen as a black, film-like deposit enveloping the yellow, hard-cooked yolk. Although this film is not encountered to any extent in a fresh egg, its formation can, in any case, be largely avoided—provided aging of the egg has not been carried too far—by taking care not to prolong the cooking period unnecessarily, and by being careful to cool the hard-cooked egg immediately upon removal from the hot water.

Care of eggs in the home. *Fresh eggs for short periods.* When eggs are held for several days in the home, they should either be kept in the carton in which they were purchased or put into a covered bowl and placed on one of the coldest shelves in the refrigerator. The shells should not be washed, since this would remove the protective mucous covering. However, just before the eggs are used for any purpose in which they are broken-out of the shell, washing is essential.

Home storage of eggs. For longer storage of eggs in localities where a large and inexpensive supply is available in spring months, fresh eggs may be preserved in mineral oil or water glass, both of which materials effectively seal pores in the shell. Water glass has an advantage over oil in that,

being alkaline in reaction, the eggs become surrounded with a solution that prevents growth of microorganisms.

For oil-dipping of eggs, a light grade of mineral oil is used. This is warmed slightly and the eggs, held in a wire basket, are dipped into it, drained, and then placed in clean containers and stored in a cool cellar. Eggs should be several hours old when they are oil-dipped, and it is essential that they be clean without necessity for washing.

For storing in water glass, a clean crock rinsed with boiling water should be used. The usual rule is to dilute 1 quart of liquid water glass with 9 quarts of water which has been boiled and cooled. Eggs are immersed in this solution and stored in a cool place. When introduced into water glass, eggs should not be more than one day old and, as in oil-dipping, they must be clean when gathered, since in both cases the mucous covering should not be washed from the shell.

Commercial cold storage of eggs. *Why the need for storing.* More than half of the yearly production of eggs in the United States is during the months of March through June; and it is during these months that a large number of eggs are placed in commercial cold storage in order to equalize the supply throughout the year. Recently also, large numbers of eggs are either frozen or, to some extent, dried; eggs preserved by these two methods have found little use in home cookery; therefore, these methods will not be considered further in this discussion.

Conditions. The usual period for holding eggs in commercial cold storage is from six to seven months, and in order that eggs may maintain high quality during this time, their initial quality must be excellent. To insure this, hens producing the eggs should be kept in clean surroundings; the eggs should be gathered several times a day, so that they may be cooled quickly from the warm atmosphere of the hen house; finally, after the eggs are gathered, they should be held at temperatures between 40 and 55° F. until they are placed in the cold storage rooms. Sterile or infertile eggs

are preferred for cold storage purposes because they are less subject to deterioration.

In the cold storage rooms, temperatures of from 29 to 31° F. and a relative humidity of between 90 and 95 per cent are maintained. These conditions retard passage of water and carbon dioxide from the egg contents through the porous shells; they also inhibit normal chemical changes that the components of eggs undergo upon aging. As a result, eggs held in cold storage show little loss in weight and little increase in size of the enclosed air space. Also, under these storage conditions, there is no significant increase in alkalinity of the egg contents, and there is a minimum of thinning of the thick portion of the white.

Recently it has been found that loss of carbon dioxide from eggs can be almost entirely prevented by introducing a small percentage of carbon dioxide into the cold storage rooms. Oil-treating of eggs, so that the shell becomes impregnated with an odorless and tasteless oil, is another measure that is sometimes practiced in commercial cold storage of eggs in order to check normal aging with undesirable consequences.

EGG COOKERY

Coagulation of egg proteins. When eggs are heated, the protein components coagulate at relatively low temperatures. Coagulation temperatures are not exact, but lie within a range which, according to Lowe, varies from 140 to 149° F. for proteins of egg white, and from 149 to 158° F. for those of egg yolk.³ For proteins of whole egg, the coagulation temperature range is similar to that for proteins of egg yolk. The coagulum formed is a smooth, more or less jelly-like mass, which can enclose within it relatively large amounts of water, together with any solids that are dispersed in the water. However, if the egg is held at the coagulation temperatures for too long a time, or if it is heated to temperatures

³ Lowe, B., *Experimental Cookery*, 3rd ed. New York: John Wiley & Sons, Inc., 1943, p. 347.

higher than those required for coagulation of the proteins, the resulting coagulum is toughened; also, it tends to shrink and, in so doing, squeezes out some of the contained liquid. This latter phenomenon is known as *syneresis*, and provides an explanation for the curdling of custards and the occasional watery mass of scrambled eggs.


Uses of eggs in cookery. *Contribute to various meals.* Eggs cooked in any one of many simple ways—in the shell, scrambled, poached, or fried—comprise part of a favorite American breakfast. In more elaborate products, such as omelets, soufflés, or timbales, they serve admirably as a central dish in the main course of a lunch or a simple dinner, replacing the customary meat. This substitution for meat is legitimate from a food value viewpoint, since eggs and meat have several nutrients in common, including proteins, riboflavin, and compounds that contain iron. These egg dishes also lend variety to menu planning.

Use in various food mixtures. In addition to these uses, eggs are incorporated into many food mixtures as follows: In some instances they function to contribute flavor and color to the mixture. In other mixtures, eggs are introduced for the purpose of providing stabilizing agents for the emulsions or foams concerned. In still other instances, eggs are used either for the purpose of coating or clarifying, or of binding. Finally, they are used for thickening food mixtures. Discussions of these several uses of eggs follow.

To contribute flavor and color. These uses of eggs are, as a rule, incidental to more important ones. For contributing *flavor*, high-quality fresh eggs are desirable, and for *color* those with the darker yellow yolks are preferable. Cakes and custards which include eggs among ingredients have a rich yellow color that adds greatly to the attractiveness of the product.

For stabilizing emulsions and foams. As components of mayonnaise, the proteins of eggs *stabilize the oil-in-water dispersion or emulsion* by concentrating at the surfaces of

dispersed fat globules, thereby checking their coalescence into large globules that would automatically separate.) This is in contrast to French dressing, in which, upon standing—since this dressing contains no egg—fat globules do coalesce to form, eventually, the familiar fat layer at the surface.

In a foam of beaten egg white—whether used for making a meringue, or introduced into a food mixture in order to incorporate air—the proteins of egg function to *stabilize the air-in-liquid dispersion*. In such a dispersion, air bubbles, becoming enveloped by protein films, are protected against coalescence and their colloidal dispersion is thus indefinitely prolonged. 

For more details in regard to the functioning of egg proteins in prolonging the life of emulsions and foams, the reader is referred to pages 371–373.

For the purpose of coating, clarifying, or binding. These three uses of eggs depend upon the heat coagulation of egg proteins. The following are examples:

Croquettes and similar products that are dipped in beaten egg and then cooked in hot fat acquire a surface that becomes sealed by the immediate coagulation of egg proteins in these areas, and this *coating* renders the product less susceptible to further fat penetration.

When either clear bouillon or consommé is desired, it is heated with a small amount of egg, the dispersed proteins of which, upon coagulation, enmesh suspended particles which can be removed, along with the coagulum, by straining. The bouillon or similar product is thereby left *clear and sparkling*.

The proteins of eggs function as *binding material* throughout mixtures, such as croquettes, where, owing to coagulation, they serve to hold the other ingredients in place. The coagulated proteins of eggs also function as *binding material* in certain finished flour mixtures, such as cakes and quick breads, in which they contribute in a secondary role to the structural framework of the mixture, the gluten proteins of flour serving in first place in this capacity (p. 74).

For thickening of food mixtures. When eggs are used for this purpose, it is again the property of heat coagulation of their proteins that is involved, the thickening being accompanied by the unique tendency of the coagulating proteins to capture and hold, within the resulting coagulum, other ingredients of the food mixture. Furthermore, if the process is skillfully supervised, the thickened mass is smooth and uniform throughout. Custards illustrate this use of eggs, a more detailed discussion of which follows. •

Custards. In general, in making a custard, a thoroughly dispersed mixture of milk, egg, and sugar is heated until egg proteins are sufficiently coagulated to hold enmeshed, in more or less even distribution, all other components of the mixture in the manner just described.

Two types of custards can be made, *baked* or *soft*, according to the manner in which the mixture is cooked. For a *baked custard*, the uncooked mixture—beaten egg well mixed with milk, sugar, and flavoring—is poured into a baking dish, which should be placed in a pan of hot water, and baked in a slow oven, about 325 to 350° F., until the egg proteins are coagulated. This type of custard is uniformly smooth and jelly-like; when cold, it is firm enough to be unmolded from a small dish such as the conventional custard cup. For a *soft custard*, the uncooked mixture is placed in a saucepan over water which should be kept just below the boiling point. The mixture should be stirred constantly as it is heated, until the proteins are sufficiently coagulated to thicken the mass. Such a custard is smooth and velvety and, unlike baked custard, can be poured into a serving dish.

Coagulation temperatures for proteins vary with ingredients. The temperatures at which egg proteins coagulate, and in so doing cause thickening to occur, are *higher for custards and similar mixtures than for the undiluted egg*; also coagulation temperatures vary considerably according to the *proportions of other ingredients* used. For example, a cus-

tard which calls for 2 eggs for each cupful of milk will thicken at a lower temperature than one in which only 1 egg to the same amount of milk is used. Hence the former custard mixture will naturally require a relatively shorter cooking period. *Sugar* has a retarding effect upon heat coagulation of egg proteins; therefore mixtures which include larger amounts of sugar, 2 or 3 tablespoonfuls rather than only 1 tablespoonful for each cupful of milk, must be heated to higher temperatures for desired coagulation of proteins. Since *the coagulation temperatures for the proteins of egg yolk are higher than for the proteins of the white*, a custard in which egg yolk alone rather than whole egg is used requires a higher temperature for protein coagulation. Thus if 2 egg yolks are substituted for 1 whole egg, a higher temperature and a longer cooking time are necessary for this mixture.

Because of these variable factors, the cooking of either type of custard mixture requires very careful attention in order that coagulation of egg proteins may be carried only just far enough to give maximum thickness to the product, since beyond this point the coagulum has a marked tendency to toughen, shrink, and squeeze out some of the liquid. When such over-heating does occur, liquid will drain from a baked custard as it stands and a soft custard will look rough and curdled.

Customary tests. In order to determine when a custard has reached the just-right degree of protein coagulation, the following tests are customarily applied. *To test a baked custard*, a sharp knife is carefully inserted and withdrawn; if the knife when withdrawn is dry, the custard is done. *To test a soft custard*, the experienced person observes the character of the film as it coats the stirring spoon; when the film is thick and velvety in appearance, this type of custard has reached the finished stage. Observance of these practical tests, and following them by *immediate* cooling of the finished custard below coagulation temperatures of the egg proteins, will always insure an excellent product.

QUALITY STANDARDS AND CONSUMER GRADES OF EGGS

Quality standards. (See Fig. 12.) *Status of state and federal control.* Since eggs are a highly perishable food and are marketed often at long distances from production centers, a practice has been set up for separating them into classes which indicate the quality that may be expected when the eggs are eventually broken open for use. Quality of eggs has to do with their desirability for human food, as influenced by internal appearance and flavor, also by external or shell appearance. Many individual states have long had laws with established standards for governing retail trade as to eggs, and in some states these laws are compulsory. But such laws differ among states. Therefore, in order to bring about uniformity of practice in rating quality of eggs, thereby facilitating egg marketing throughout the country, the United States Department of Agriculture has set up "Official United States Standards for Quality of Individual Shell Eggs." Hence, whenever shell eggs are inspected by official graders of the United States Department of Agriculture, these are the quality standards that are observed as a basis for classifying the eggs under the various so-called U. S. Consumer Grades (p. 190).

Classification and labels. Although resorting to federal service for grading of eggs is purely a voluntary matter on the part of egg dealers, when this service is employed, government graders inspect, grade, and classify eggs submitted to them, then seal them into cartons and attach a label which carries grade certification and date of grading. According to U. S. quality standards for eggs with clean unbroken shells, four classes are specified, which, in decreasing order of desirability, are: *AA Quality*, *A Quality*, *B Quality*, and *C Quality*. Eggs with dirty, unbroken shells are classified as *Stained or Dirty*; and eggs with checked or cracked shells are classified as *Check or Leaker*.

QUALITY

EGGS

STANDARDS

QUALITY

AA
Excellent
Table Eggs

A
Fine
Table Eggs

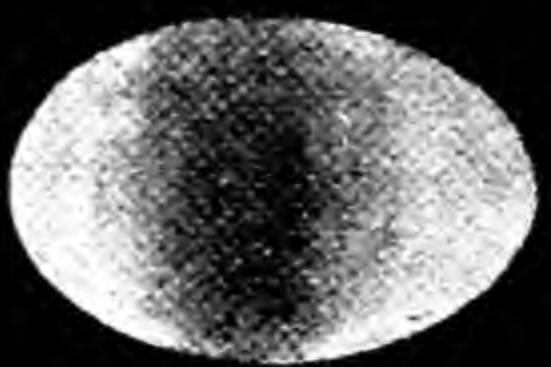
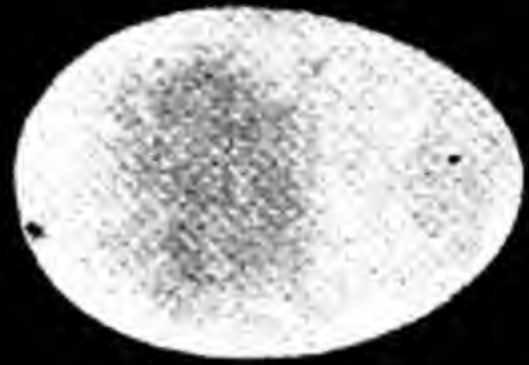
B
Table, Cooking
and Baking Eggs

C
Cooking and
Baking Eggs

APPEARANCE

CANDLING

SHELL
YOLK
WHITE
AIR CELL

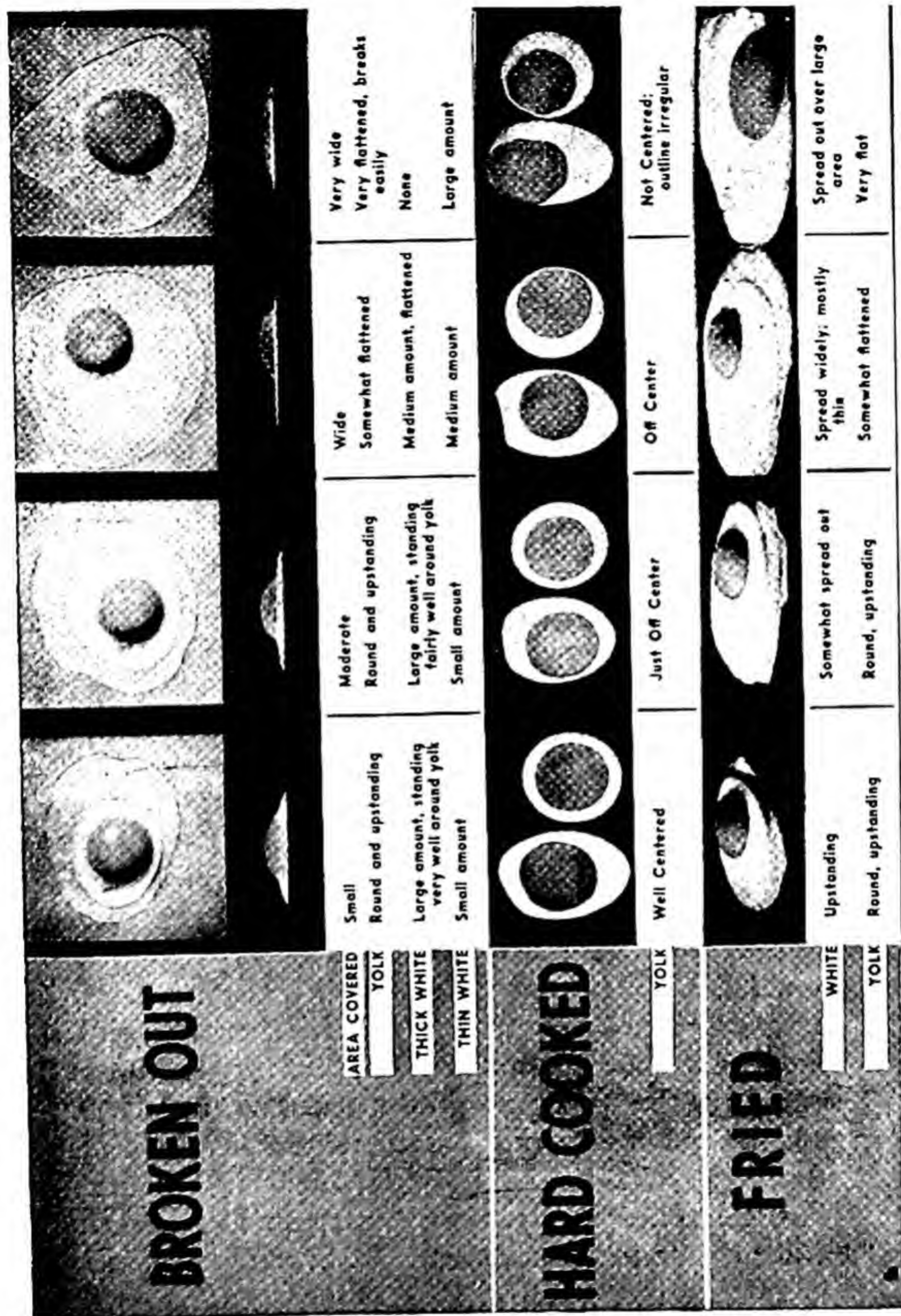


Clean and unbroken
Well centered
Outline slightly defined
Clear and firm
1/4-inch or less in depth,
practically regular

Clean and unbroken
Fairly well centered
Outline fairly well defined
Practically free from
defects
Clear and reasonably firm
1/4-inch or less in depth,
practically regular

Clean, unbroken, may be
slightly abnormal
May be off center. Outline
defined, slight defects
allowed. May be slightly
enlarged and flattened
Clear but slightly weak
1/4-inch or less in depth,
movement up to 1/4-inch

Clean, unbroken, may be
abnormal
May be off center, plainly
visible. Some defects
permitted. May be
enlarged and flattened
Weak and watery, small
blood clots permitted
May be over 1/4-inch in
depth, may be bubbly
or free



(Courtesy of Poultry and Egg National Board, Consumer Information Service.)

Fig. 12. Quality standards for eggs.

Basis for judging quality. *Shell quality* is easily judged by simple examination. But to judge *interior quality* a "candling" process is used which renders contents visible. Candling is accomplished by holding the egg before a small opening in a box which encloses a light of specified intensity. By this means, depth of air cell can be observed and whether or not it is stationary, as it should be in a fresh egg. Firmness of white, one of the criteria of quality, is judged by yolk shadow, which determines its position with reference to the white. A firm white permits only slight movement of the yolk, so that it remains well-centered and does not move nearer to the shell as the egg is twirled before the candle; therefore such an egg shows an indistinct shadow. This is in contrast to a yolk shadow that is more clearly distinct in an egg with a thinner white which permits greater movement of the yolk. When eggs are of low quality classes, size and shape of the yolks, as well as their position, are also points for consideration in determining their classification.

Detailed specifications in regard to criteria which determine quality for eggs are given in the publication cited below.⁴

Consumer grades. Based upon United States Standards of Quality, the Production and Marketing Administration of the United States Department of Agriculture has set up tentative specifications for consumer grades and weight classes of eggs.⁵ These specifications are designated as: *U. S. Consumer Grade AA*, *U. S. Consumer Grade A*, *U. S. Consumer Grade B*, and *U. S. Consumer Grade C*. Each grading as it appears on the container guarantees to the consumer that at least 80 per cent of the eggs concerned are of specified U. S. quality, with the possibility that the remainder of the eggs may be of lower but still of definitely specified U. S. quality classes. This tolerance of allowing 20 per cent of eggs in each Consumer Grade to fall below the U. S. quality class is

⁴ *United States Standards for Quality of Individual Shell Eggs, Order of Promulgation of Standards*, United States Department of Agriculture. 1946.

⁵ *Tentative U. S. Specifications and Weight Classes for Consumer Grades for Shell Eggs*, United States Department of Agriculture. 1946.

permitted in order (1) to take care of variable interpretation of grades on the part of different graders, and (2) to allow for normal changes that may occur, even under favorable conditions, during reasonable time periods between grading and subsequent inspection.

Eggs of edible quality that fail to meet grade qualifications, or that have been contaminated by smoke, chemicals, or other foreign materials to the extent that their character, appearance, or flavor has been affected, are classed as *No grade*.

U. S. weight classes for consumer grades of eggs are based upon net weight per dozen. There are five such weight classes labeled as follows: *Jumbo* (28 oz.), *Extra large* (26 oz.), *Large* (24 oz.), *Medium* (21 oz.), and *Small* (18 oz.).⁹

Official grading of eggs is a forward-looking step in the marketing of a highly perishable food. It places an incentive upon all the various handlers of eggs, from producer on the farm to retailer in the town or city, to observe such practices as are necessary to maintain high quality in eggs. And, finally, it provides the consumer with the means of knowing the quality to expect in eggs which are purchased, provided they carry such labeling. It also provides the housewife with a basis for a selection of eggs for various uses: top-quality eggs for table use, and those of a lower but still good grade for various other cookery uses. *

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⁹ *Ibid.*

CHAPTER XV

MEATS

Introduction. *Meaning of term.* In its more inclusive meaning, meat is a term which applies to the flesh of all edible animals, including the flesh of mammals, fish, poultry, and game. But in a more limited sense, it is common practice to designate as meat just the flesh of slaughtered mammals and to include in this category meats of cattle origin (beef and veal), of hog origin (pork), and those from sheep (lamb and mutton). It is a study of meats in this limited sense with which this chapter is concerned.

Differentiating terms. *Veal* is distinguished from beef in that it comes from the beef animal between the ages of three to twelve or fourteen weeks. Genuine *spring lamb* comes from sheep up to the age of six months; *lamb* comes from sheep up to about fourteen months, while meat coming from older sheep is classed as *mutton*. No age significance is attached to cuts of *pork*, due to the fact that most hogs are slaughtered and marketed between the ages of seven and twelve months.

Yearly consumption. The American people have come to consider these meats as very important items in their diet. A careful inspection of this table, in which figures are given showing the average per capita consumption of meats from these three sources, serves to confirm this statement.

Reasons for popularity. There is no doubt that the chief reasons, since prehistoric times, for the popular appeal of meats have been their high flavor and the sheer animal

PER CAPITA CONSUMPTION OF MEATS IN POUNDS
DURING YEARS FROM 1938 TO 1944¹

	Beef	Veal	Lamb and mutton	Pork	Total meats
1938	54.0	7.6	6.9	57.8	126.3
1939	54.4	7.5	6.6	64.3	132.8
1940	54.7	7.3	6.6	72.4	141.0
1941 ²	60.5	7.6	6.8	66.5	141.4
1942 ²	61.2	8.0	7.2	61.5	137.9
1943 ²	49.6	7.9	6.4	72.4	136.3
1944 ²	53.4	11.3	6.7	77.0	148.4

strength that man, down through the centuries, has sensed from a high meat diet. This latter attitude has not been imaginary, since nutritionists have found that meats actually do rank high in food value in that they provide proteins of excellent quality, fats, some minerals, and certain of the vitamins.

Another and more modern reason for the popular appeal of meats, in this instance an aesthetic appeal, is their attractive appearance when carefully prepared, cooked, and served. And, fortunately, it is quite easy to arrange menus of pleasing variety around any selected meat as the central dish.

TYPES AND STRUCTURE OF MEAT CUTS

Two general types. The majority of cuts of meats are *skeletal or muscular cuts*, obtained from muscles which cover and surround the skeletal framework of the animal. In all living animals these tissues have common supporting and motor functions; hence the meats from these sources, whether from muscles of cattle, hog, or sheep, contain much the same components (p. 196). Besides skeletal or mus-

¹ *Agricultural Statistics*, United States Department of Agriculture, 1946, Table 467.

² Civilian consumption only.

cular cuts, several of the *animal organs* are commonly used for food. Chief among these are the heart, stomach, liver, pancreas, kidney, and thymus (sweetbreads).³ Physiologically, organs differ from muscles in that the cells composing their predominating tissues are more highly differentiated and specialized in their respective functions than are the cells of muscular tissues. Toward such specialized services in the living animal, organs become equipped with large proportions of certain requisite foodstuffs that are peculiar to their specific and respective functionings, and some of these foodstuffs persist when, later, the organs are employed as meats.

Skeletal or muscular cuts. Component parts. *Muscle tissue, connective tissues and bone, fats, nerve tissues, and blood* make up the component parts of skeletal meat cuts; but muscle tissue constitutes the bulk of the edible parts. However, since the quality of skeletal cuts is influenced not only by the nature of the muscle tissue in itself but also by the character of the connective tissue with which it is in intimate structural association, and by the fat distribution, an understanding of these relationships is of considerable importance.

Muscle tissue. The units of muscle tissue are *individual cells* about one to two inches in length and about $\frac{1}{200}$ of an inch or less in diameter. The ends of the cells taper to points. Because of their great length in comparison to their diameter, muscle cells are frequently spoken of as *muscle fibers*. Each cell has a containing membrane or "cell wall." All cells are held together by means of fine connective tissue to make up a bundle of cells, which is called a *fasciculus*. (Fig. 13.) Many fasciculi are, in turn, held together, also by connective tissue, to make a *muscle, large or small*, according to the number of fasciculi included. Finally, muscles are held together by heavier connective tissue and they are held to bones by tendons.

³ The pancreas is also sometimes sold as sweetbreads.

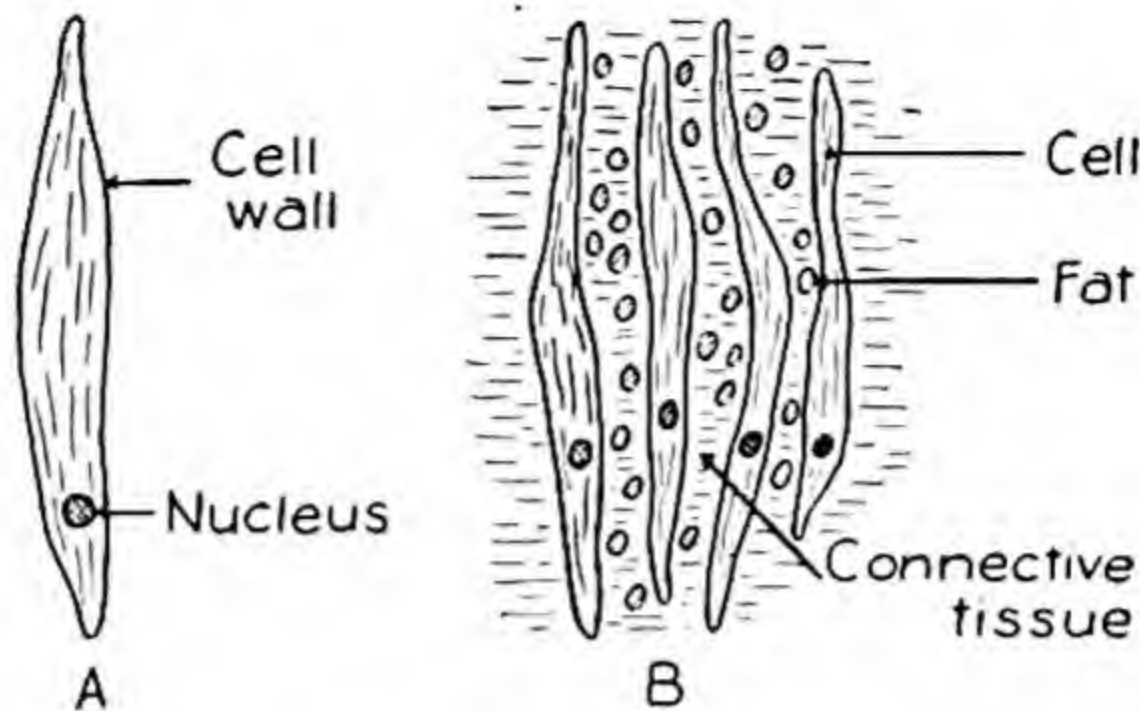


Fig. 13. Diagram: A. Of muscle cell; B. Of fasciculus.

Such, in brief, is muscle structure, and individual cuts of meat as a rule contain several muscles, usually in cross sections.

Connective tissues. As implied above, connective tissues are intimately distributed between and throughout the muscles, where they play a connecting and supporting role.⁴ They are composed of relatively few cells but much intercellular material which varies in elasticity and tensile strength according to its muscle association and location, also the special function that it fulfills therewith. These connective tissues are characterized as *white fibrous* and *yellow elastic*, and their properties of tensile strength and elasticity vary according to the proportions of the two principal proteins, **collagen** and **elastin**, which contribute to their make-up. Collagen, which is in the form of tough fibers or fibrous sheets, predominates over elastin in white fibrous tissue, while elastin, which, as the name implies, is somewhat elastic in character, predominates over collagen in yellow elastic tissue. Collagen and elastin are albuminoids (p. 383), hence they do not form dispersions, either true or colloidal, in water

⁴ **Bone** is considered as connective tissue in which intercellular materials have become impregnated with precipitated salts, chiefly insoluble calcium phosphate and calcium carbonate. The protein, collagen, is also found in bone structure as well as in other, but less dense, connective tissues.

alone or in salt solutions. *Collagen reacts with water in hydrolysis to produce gelatin* at temperatures at which meats are cooked, thereby bringing about a tenderizing effect. The same is not true of elastin. (p. 198.)

Fats of skeletal cuts. Fats are deposited in the living animal between muscles and the skin; associated with connective tissues, they also lie in more or less large deposits (depot fat) between muscles; and, within the muscle structure itself, they are distributed either between individual cells or between cell bundles (fasciculi). And fats remain distributed in this manner in meat cuts. With the skin of the animal removed, the outer fat layer appears as a covering on outer portions of the cut; the depot fat appears as relatively large masses; those fats located within the muscle structure appear as small flecks and are referred to as marbling fat.

Blood vessels and nerve tissues. Remains of blood vessels and nerve tissues, interspersed among the connective tissues and bones or sections of bones, complete the structural parts of skeletal cuts of meat.

Organ cuts. Meat cuts of organs origin differ from skeletal or muscular cuts in that they do not contain bone; but in common with muscle, these specialized tissues are held together by connective tissues and are impregnated with blood vessels and nerve tissues. Since, in the living animal, organs are surrounded by layers of soft fat deposits for the purpose of keeping them in place and cushioning their movements, the meat cuts made from these organs are often surrounded by such fats.

COMPONENTS OF MEATS

Of muscle cells origin. Meat fibers of muscle origin contain about 75 per cent water and 25 per cent solid material. Proteins comprise about four-fifths of the solid material; other solids include some true fats, larger amounts of fat-like substances called phospholipids (p. 380), inorganic substances, and vitamins. Some details concerning these components are as follows:

Proteins. Protein components of muscle cells include the simple proteins (p. 382) *muscle globulin*,⁵ which constitutes approximately 70 per cent of cell proteins, and *muscle albumin*.⁵ *Muscle hemoglobin*⁵ is present in small amounts in red meat fibers, but only in negligible amounts in light-colored fibers. Distinguishing solubilities of globulins and albumins are listed below; their comparative solubilities are of considerable significance in the preparation of meat dishes.

Muscle globulin	non-dispersible in water alone, but forms a fairly permanent colloidal dispersion in dilute salt solution.
Muscle albumin	dispersible in water alone and in dilute salt solution.

In the living animal, like hemoglobin of the blood (p. 199), muscle hemoglobin plays a part in "binding" the oxygen supply that is taken into the cells from the blood stream. So it is not surprising that, in red meats, muscle hemoglobin functions in color changes that occur when muscle fibers are cut and their contents released into contact with air.

Fats and phospholipids. As said previously, active cells contain very little simple fats, but they do contain important fat-like substances, called phospholipids (p. 380), which are fat-phosphoric acid complexes; and these phospholipids persist in related cuts of meats.

Carbohydrate. Muscle cells of the living animal contain *glycogen*, which is sometimes called animal starch, since it has starch-like properties and is found only in animals. It constitutes the reserve supply of carbohydrate of living muscle tissues for the purpose of playing its part in the making of cell energies. It forms colloidal dispersion, hence is unable to leave the cells (p. 5). But, immediately upon the death of the animal, the glycogen begins to disappear—made into lactic acid and other substances—so that only traces of glycogen remain in meat.

⁵ Muscle globulin and muscle albumin are frequently called respectively *myosin* and *myogen*. Muscle hemoglobin is frequently called *myohemoglobin*. Always, a "myo" prefix is significant of a protein of muscle cells origin.

Vitamins. Among important components that occur in muscle cells the vitamins riboflavin and niacin should be listed, since they are present in the muscle tissues of cattle, hogs, and sheep; and, fortunately, these vitamins persist in muscle meats obtained from these animals. The meat of hog origin is uniquely rich, also, in thiamine.

Inorganic components. The inorganic materials of muscle cells, hence those present in meats of muscle origin, are potassium (chiefly) and sodium chlorides, soluble phosphate salts, and soluble magnesium and calcium salts. Iron is present as a constituent of muscle hemoglobin.

Meat components from fat tissue. The fats that are components of fatty tissues of meat cuts are almost entirely *simple fats* in character. A fat-like substance, of no cookery importance but of considerable physiological significance, that is associated with fats of fatty tissue is called *cholesterol* (p. 381). It is soluble in fats but insoluble in water and salt solutions. This accounts for the fact that in the living animal cholesterol is found distributed, in small amounts, chiefly where fats are located; and after the animal is killed, it continues in this association with fats in the meats concerned. Incidentally, cholesterol is also present in other fatty foods of animal origin such as lard.

Meat components from connective tissues. The components contributed to meats that are peculiar to connective tissues are *collagen* and *elastin*. The relative proportions of these two proteins in meat cuts have great significance in relation to the tendering effect accomplished during the cooking process. This is due to the fact that, when subjected to heat and moisture, *collagen is changed to gelatin*, a soft, tender product; but no such change is brought about in elastin. It follows, therefore, that cuts of meat in which white connective tissue predominates over the yellow variety become tender upon cooking; but cuts which contain much yellow connective tissue can only be made tender by chopping or grinding.

From organs. With the exception of iron and vitamins,

components of meats from organ tissues—proteins, minerals, fats and fat-like substances—are the same as those from muscle. But meats of organs origin do contain relatively larger amounts of iron-containing substances, also more riboflavin, thiamine, and niacin. And it is important to note that any vitamin A which is contributed to the diet from meats is derived almost exclusively from organs, not muscle; liver is outstanding in this respect.

Hemoglobins of meat. Hemoglobins of both blood and muscle are regarded as pigments, in that they are the components of meats which are responsible for their red or pink color. Since blood hemoglobin occurs only in blood, it is present in meat cuts of all types only to the extent to which blood is retained in them at time of slaughtering the animal.

The two hemoglobins are similar in chemical make-up; both contain a protein radical called globin and an iron-containing radical called *heme* (formerly *hematin*); therefore, in a way, both may be looked upon, inclusively, as one protein component of meat. In the living animal, both blood and muscle hemoglobin function as oxygen carriers, and they exhibit some “oxygen-binding” capacity later in meats. Un-oxygenated hemoglobin (sometimes incorrectly referred to as reduced hemoglobin) is dark red or purple in color; in this form it is responsible for the dark red color that is so characteristic of freshly cut surfaces of beef muscle; but upon standing exposed to air for several minutes, the hemoglobin at surface areas “binds” oxygen to make oxyhemoglobin, which is brighter red in color.

When meat is cooked, hemoglobins turn a bright red at first, then with increasing temperatures *hemin* is produced, which is dark brown. Therefore, if there is a sufficient amount of hemoglobin in the meat, as in beef and lamb, the cooked meat is brown, but when smaller amounts are present, as in veal and pork, the cooked meat is gray.

Meat extractives. Extractives is the name given to a group of compounds of metabolic significance which are

present in meat cuts in varying amounts. They include nitrogen-containing substances called creatine, creatinine, and purines. Extractives are lacking in food value but play an important role in contributing flavor to meats. *Meat extracts* is the term applied to the concentrate of extractives which is obtained after separating the latter from the meat. This is accomplished by treating finely ground meat with hot water which carries out the extractives, along with materials not coagulated by heat such as lactic acid and mineral salts; most of the water is then evaporated. Meat extract is very dark brown in color and is frequently used to enhance the flavor of soups and gravies. Bouillon cubes are very largely composed of an extract that is made from beef.

GRADING AND INSPECTION OF MEATS

Why important. Following upon the considerable growth of the livestock industry in the United States and the establishment of large packing-house centers, often at points distant from consuming markets, it eventually became necessary, both for those engaged in the industry and for the protection of consumers, to establish orderly and standardized measures upon which to carry on marketing procedures. Consequently, taking into consideration practices commonly in vogue at the time, pioneers in the field—including representatives of the United States Department of Agriculture, of State Agricultural Experiment Stations, and of the livestock industry—set up a system of standard market classes and grades of meat.

A description of these established classes and of standards taken into consideration in determining quality-grades of meats follows.

Classes. In the language of the meat industry, "class" designation has to do with the sex and sex condition of the animal, each of the three types of meat animals—cattle, sheep, and hogs—being divided into *three classes* on this basis as follows: (1) whether male or female; (2) if male, whether

or not unsexed, and if unsexed, whether before or after reaching sexual maturity; and (3) if female, whether or not there have been offspring.

For the purposes of this study, the name by which each of the three classes for each type of animal is designated is not important, since class distinction needs to be considered only because it has an effect upon the quality-grading of the meat. Thus, in general, the best quality (desirability) of meat is obtained either from the male animal which has been unsexed before maturity, or from the young female before she has borne young. However, other factors, including breeding of the animal, its age, care, and feeding, also affect quality of meat obtained.

Quality-grading. Grading of meat from the standpoint of quality (desirability) is in respect to those factors which, being inherent in the animal itself and its carcass, affect appearance, tenderness, juiciness, and flavor of the meat. With a few minor exceptions, standards for quality-grading are similar for all three types of animals and a brief summary of these follows.

Criteria (standards) for quality-grading. In the meat industry, terms that have come to be applied to criteria for quality-grading of meats are: *conformation*, *finish*, and *quality*.

Conformation applies to the shape of the animal before slaughter. Good conformation shows a compact body, wide and deep in proportion to length, and one with well-rounded, thick flesh. Such a build insures a high proportion of weight in the rib, loin, and round sections of the carcass, and it also insures a thick, compact shape in the individual cuts to be obtained from these sections.

Finish applies specifically to fat: to the amount of fat that covers and lies between the various muscles, that surrounds the internal organs, and that is distributed within the muscles (marbling fat). Good finish requires an even and smooth covering of fat, about one inch in thickness, over the

ribs and loin, and a large amount of marbling fat (except in veal). All this shows up in carcasses, although an experienced observer can distinguish *finish* simply by looking the animal over while it is still on hoof.

Quality, as one of the criteria for grading meats, *is judged from meat cuts* obtained from the carcass. It characterizes: the flesh of the meat cut; the size and condition of the bone; the condition of the fat; and the quantity and thickness of the connective tissue.

Good quality requirements are as follows: The *flesh* must be firm; the fasciculi should be small, contributing thereby a fine grain and velvety texture to the lean part of the cut. The *color of the flesh* must be characteristic of the animal origin—a bright cherry-red for beef, pinkish-red for lamb, and greyish-pink for veal and pork. The *bone* must be relatively small and, where cut, must be red and spongy in appearance, denoting youth; this is in contrast to white, hard, and flint-like bone which denotes age. The *fat* must be white and firm, and there must be plenty of marbling fat. Finally, there must be a relatively *small proportion of connective tissue*.

It usually follows that these five quality characteristics rate high in cuts that are derived from animals of good conformation and finish.

Grade designation. The final grade designation of the animal carcass is determined by its degree of excellence with respect to the three criteria: conformation of the animal or carcass, finish as to fats, and quality as to cuts obtainable.

Six grades are specified for beef which in decreasing order of quality-grade are called: *prime, choice, good, commercial, utility*, and *cutter and canner*. Similar terminology is used for designating grades of lamb and veal, but there are the following exceptions: for lamb the term *cull* is used instead of *utility*, and there is no lower grade; for veal there is no *prime* grade, and the lowest grade is called *cull* instead of *cutter and canner*. For pork, grades of 1, 2, and 3 are used.

Meat inspection. As to wholesomeness. Under the Federal Meat Inspection Act of 1906,⁶ all meat entering *interstate commerce must* be inspected by federal inspectors. This inspection is designed to protect the consumer in that it guarantees that such meat comes from healthy animals and is slaughtered under sanitary conditions both as to plant and health of operators. It also guarantees that each cut-



Fig. 14.

ting operation, subsequent to slaughter, meets accepted standards of sanitation. All meats so inspected and found acceptable in all respects, as stated, are stamped with a round, purple stamp. The ciphers at the top of the seal (Fig. 14), indicate the position where a number is placed which identifies the particular slaughtering house concerned.

The Federal Meat Inspection Act does not have jurisdiction over meat obtained from animals slaughtered and sold *within state borders*. It follows, therefore, that the consumer of such meat is unprotected as regards wholesomeness, unless there are state or local laws which serve as guarantees in this connection.

Meat inspection as to quality. As has been pointed out, the Federal Meat Inspection Act is concerned *only* with the wholesomeness of meat, not with its quality, meaning its desirability. But beginning in 1927, the United States Department of Agriculture undertook to make available to packers a *quality-grading* by federal graders. At first this inspection applied only to beef, but by 1931 the service was expanded to include lamb, mutton, and veal. It should be emphasized that, in contrast to grading as to wholesomeness,

⁶ Sherman, H. C., *Food Products*, 3rd ed., Appendix B, "Federal Meat Inspection." New York: The Macmillan Company, 1933.

which is mandatory, quality-grading is an optional service of which a packer may avail himself or not as he pleases.

For quality-grading of meat, federal inspectors turn to the criteria previously presented (p. 201), and they employ grade designations as listed on page 202. Provided the plant which accepts this service comes under the jurisdiction of the Federal Meat Inspection Act of 1906, a second stamp is imprinted upon the meat which has specific reference to its *quality*, as for example: *U. S. Choice*, or *U. S. Good*, etc. On the other hand, when a federal inspector grades meats that do *not* come under the jurisdiction of the federal law but are from animals slaughtered and sold within the borders of the same state, then the quality-grade stamp does *not* carry the letters "U. S." but simply the words *Prime*, *Choice*, and so forth.

In some instances a packer may grade the meat himself, rather than employing a federal grader; if so, the stamp designates the grade by letters as follows: *AA* (for choice), *A* (for good), *B* (for commercial), *C* (for utility for beef or cull for lamb), and *D* (for cutter and canner for beef or cull for veal).

TENDERNESS OF MEATS

Varies with quality-grade. Generally speaking, meats of top quality-grades are more tender than those of lower quality-grades. Since this is true, and since tenderness of meat is an important contributing factor to palatability, it is essential that the person who is responsible for the selection of meats should be able to recognize the three standards of quality-grading—conformation, finish, and quality—as reflected in individual cuts.

Varies with location of cuts. But irrespective of grade, certain cuts of meat derived from any animal are relatively less tender than others. Although details of cutting differ among the three types of animals, the most tender cuts always lie along the backbone and ribs, less tender cuts coming, as

a rule, from the shank, shoulder and neck, and under parts of the body. Cuts from under parts of the body, when derived from beef, are termed *flank*, *plate*, and *brisket*; when from lamb and veal, *breast* is the term applied to the cuts that are analogous to plate and brisket. The under part of the hog contributes such cuts as *spareribs*, *bacon*, and *salt pork*.

Incidentally, it will be noted that the less tender cuts include sections of muscles that are exercised as the animal walks and grazes. And it is significant that these muscles contain a large proportion of well developed or dense connective tissue which, unless modified by cookery processes, contributes to toughness. The tenderizing effect on connective tissue that is accomplished during cooking has already been referred to and will be discussed later. (pp. 206-208.)

Effect of ripening process on tenderness of meat. After the animal is slaughtered and the carcass dressed, it is placed in a cooling room, where it is held for some time to ripen. The coolers are held at temperatures of from about 34 to 38° F. in order to keep bacterial and mold action at a minimum; at the same time the humidity level in the cooler is maintained high enough to inhibit evaporation in order to avoid accompanying meat shrinkage.⁷

At the beginning of this period, rigor or a stiffening of the slaughtered animal sets in and the fat, which in the living animal is soft, solidifies. Rigor may be due to a change in certain of the muscle proteins, especially muscle globulin, which coagulate and, in so doing, cause the stiffening. After about twenty-four hours, rigor passes and the muscles begin to soften. This softening is believed to be due to autolysis

⁷ A recent ripening practice, quite limited at the present time, is that of holding the meat at higher temperatures of from 55 to 65° F. with the object of hastening the changes involved. But, because at these temperatures activities of molds and bacteria are increased, the meat is irradiated with ultraviolet light in order to prevent too great a development of these organisms. It is also necessary to provide for a high relative humidity to avoid excessive drying of the meat.

(self-directed hydrolysis) of the proteins affected, the reactions being favored by the presence of certain enzymes.

It is possible that the replacement of a portion of the proteins of muscle cells with more easily dispersible products of protein hydrolysis is responsible for the ripening and accompanying tenderizing of meats. The extent of this effect depends upon the length of time the meat is held in the coolers, and the time varies according to personal preferences of the clientele to which the particular market for the meat caters; buyers for men's clubs, for example, are inclined to select well-ripened meats, since, as a rule, men like meats which are carried along further in the ripening process than do people as a whole. But, in general, the ripening period may range from a week to possibly as long as one or two months. However, meat held for longer intervals develops a too strong or too game-like flavor for the average customer; also the fat is apt to become rancid.

Along with the products of autolytic changes, lactic acid is made from glycogen, which accounts for the fairly rapid disappearance of glycogen from muscle cells of the animal after death.

MEAT COOKERY

Object. The chief object in cooking meat is to increase its palatability by making it more attractive in appearance and more flavorful. In many instances cooking makes meat more tender and in some respects more digestible. In the case of pork, cooking is a precautionary measure from a sanitary point of view (p. 220). Cooking meats also lends interest to menu-making because it increases the variety of attractive ways in which meats can be served.

Changes effected during cooking. The appearance and flavor of meats are affected to a greater extent by cooking methods that use *dry heat* than by those that employ *moist heat* (p. 208). In dry heat methods the surface of meat takes on an attractive, glossy, brown color; the fat

becomes clear and, on the surface, slightly crisp. The flavor of meat is also enhanced by changes effected through the agency of heat: more flavorful substances are made from proteins and fats; the presence of extractives becomes apparent; and the marbling fat melts and blends with liquids emerging from muscle tissues to produce a juicy quality.

Since all of these effects are less pronounced when using moist rather than dry heat methods, when cooking meats by moist heat, it is sometimes found advisable to resort to flavorful gravies or sauces for added interest.

In *all* methods of cooking, the interior of the meat changes color according to the extent of heat penetration and the accompanying change of hemoglobin, which is red, to hemin, which is brown.

So far as *tenderness* of meat is influenced by cooking, the results are not uniform among cuts from different parts of the animal.⁸

This variation in tenderizing effect in meats during cooking is attributed in part to two opposing forces. On the one hand, there is a trend toward *toughening* as muscle fibers harden and shrink to a greater or less degree, depending upon the extent to which their proteins coagulate when heated. On the other hand, the alteration, through the agency of heat and moisture, whereby collagen of connective tissue is changed to gelatin, has a *tenderizing* effect. Which of these forces predominates depends largely upon the amount of connective tissue present in the meat cut and upon its collagen content. Thus, for cuts in which collagen is present in relatively large amounts, considerable tenderizing during cooking is possible. But with cuts which contain a small proportion of collagen, the tenderizing effect, due to the change of collagen to gelatin, may not be sufficient to offset the toughening due to the coagu-

⁸ For a more detailed discussion than is given here, the student is referred to Ramsbottom, J. M., Strandine, E. J., and Koontz, C. H., "Comparative tenderness of representative beef muscles," *Food Research*, Vol. 10 (1945), pp. 497-509.

lation of muscle proteins; indeed, such cuts may even become less tender upon cooking.

As has been pointed out previously, meat cuts in which elastin predominates can be made tender only by chopping or grinding.

Methods of cooking meats. Many methods are used for cooking meats, but from the standpoint of the environment obtained, they all fall into only two groupings: (1) those methods that employ *dry heat*, such as roasting and broiling in which the meat is surrounded by hot, dry air, also frying and pan-broiling in which the meat is cooked in contact with a hot surface; and (2) those methods in which the meat is surrounded by a *moist environment*, such as simmering, stewing, braising, potroasting, and steaming.

The main influencing factor in choice of method for cooking meat should, in every instance, depend upon the cut which has been selected. The considered rule is to use dry heat methods for tender cuts, but moist heat methods for less tender cuts. The difference in this choice of method lies in the fact that less tender cuts contain more and denser connective tissue than do tender cuts, and heat with appreciable moisture,³ as in moist heat methods, will bring about more extensive conversion of collagen to gelatin, producing, thereby, a greater tenderizing effect upon the tissues.

However, while the above rule is an excellent one to keep in mind, as a "rule" it has its proverbial "exception," because occasionally one does encounter a meat cut which, although commonly classed among less tender cuts, is nonetheless actually found to be of high quality-grade. Such a cut can be cooked by either moist or dry heat methods.

Choice of cuts. Just which cuts of meats are selected for use depends upon personal preference, cost, and availability. Cost is obviously an important factor since, as a rule, tender

³ There is always some moisture present, even when using "dry heat."

cuts—those from the rib and loin sections of the animal—are relatively expensive. Furthermore, in many communities the choice in meats is frequently very limited. Of less expensive, less tender cuts there may be a wide selection, including cuts which are not only economical, but flavorful and tender when cooked properly, and which are of high nutritional value; and these cuts can be prepared in many attractive ways.

ROASTING

Cooperative project for determining factors affecting meat cookery. Beginning about 1925, an extensive meat investigation study was undertaken as a cooperative project by the United States Department of Agriculture, the State Agricultural Experiment Stations, and the National Livestock and Meat Board, with the purpose of investigating factors which influence the quality and palatability of meats. To date, findings from these researches which affect meat cookery have led to the establishment of certain practical procedures toward obtaining cooked meats of maximum palatability. A brief discussion of these findings as they apply to *roasting* meat is given in the following sections.

Stage or degree of doneness. In meat cooked by any of the dry heat methods, there are three stages of doneness, depending upon the extent of heat treatment. These are designated as *rare*, *medium*, and *well-done*. Although these specifications apply to all types of meats, they can best be described in terms of color changes that become apparent in beef and lamb at each stage, since these meats contain relatively large amounts of red hemoglobin, which changes to brown hemin when the meats are heated. Thus, in *rare* beef and lamb, only the outer surfaces are heated sufficiently for the brown color to appear, while the inner portions retain their bright red color. In cuts cooked to the *medium* stage of doneness, the brownish color extends further inward and even the

center portions of the roast begin to lose their bright color. Finally, in *well-done* beef and lamb, all of the interior has taken on the brown color.

Degree of doneness and food use. *Beef* may be served at any stage of doneness; *lamb* either medium or well-done; but *veal* (usually) and *pork* (always) should be served at the well-done stage. In the main, which degree of cooking is selected depends upon personal liking, since all meats—pork excepted—can be safely served at any stage of doneness; but pork must *always* be well-done throughout (p. 221).

Degree of doneness and roasting times, using meat thermometer. No two cuts that are encountered in home cookery are identical either in *size*, *shape*, or *structural make-*

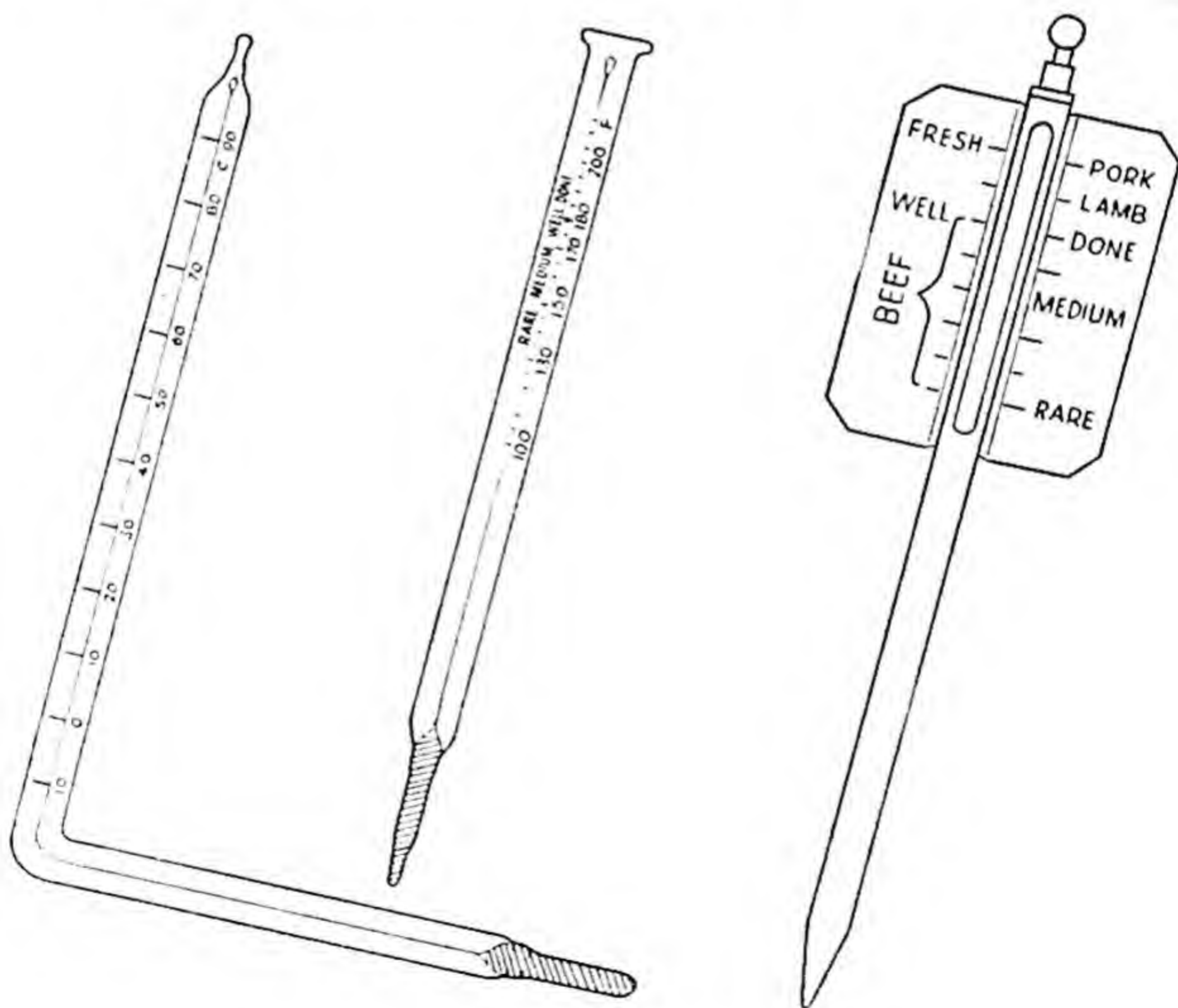


Fig. 15. Meat thermometers.

up as to proportion of lean muscle, to fat, to bone, and so forth. And all three of these features affect the time it takes for heat to reach the center of a piece of meat, hence the time required for roasting.

If the "right" degree of doneness—rare, medium, or well-done—is to be absolutely assured, a meat thermometer (Fig. 15) should be used. The usual practice of allowing so many minutes per pound of meat is less reliable. (p. 212.) It is, however, a guide as to when the cooking of a cut of meat should be started.

Approximate internal temperatures to which beef, veal, lamb, and pork should be roasted for each degree of doneness are as follows:

For beef

rare	140° F.
medium	160° F.
well-done	165–175° F.

For veal

well-done	170° F.
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For lamb

medium	170° F.
well-done	182° F.

For pork, well-done

fresh	185° F.
cured	170° F.

Effect of size of roast. Skillfully conducted experimental observations, made dependable through the use of meat thermometers, reveal that the time requirement *per pound* for roasting to a given degree of doneness is less for large than for small cuts of meat. The reason for this difference is that the diameter of a large roast is proportionately less in relation to its volume, hence less in proportion to its weight, than with a small roast. As a result, the time that is required for heat penetration to the center of a large roast is proportionately shorter than to the center of a small roast.

Effect of shape of roast. A meat cut that is compact and chunky in shape requires a longer time *per pound* to roast to a given degree of doneness than in the case of a thinner or more rangy cut. This is due to the greater compactness of the roast, hence to the smaller surface in proportion to volume that it has exposed to the oven's heat. This need

for a longer roasting period for a cut that is compact and chunky is particularly applicable to rolled roasts of beef. Such a roast usually takes from ten to fifteen more minutes per pound for roasting to a given degree of doneness than is required for a standing rib roast, that is, when both are cooked in an oven of the same temperature.

Effect of structure. The influence that structural make-up of a meat cut has upon length of roasting time is due to different rates of heat penetration in passing through muscle, fat, and bone. When fat becomes melted, heat travels through it more quickly than through muscle, and it travels more quickly through muscle than through bone; hence, results are as follows: Roasts with a thick surface layer of fat cook more quickly than do those with little or no fat covering. In meat cuts with bone located near their center, the slow rate of heat penetration through bone has little practical significance. But when bone is near the surface, as in a standing rib roast, the least-done portions are always found just above the bone, even though the meat in these areas lies near the surface, where it is exposed to the oven's heat.

Dependence only upon tables for arriving at desired degree of doneness. Since a meat thermometer is fairly new equipment and frequently not available, many cooks have learned to rely upon *time tables* that are published for this purpose. These tables¹⁰ give specific oven temperatures that have been found to be best suited for roasting all types and cuts of meat; they also give the range of time in minutes per pound that is required in each case to roast the meat cut to a given degree of doneness.

However, when one is relying upon time tables, it is also advisable to take into consideration the accurately obtained findings just discussed in regard to the factors which affect

¹⁰ *Handbook of Food Preparation*, American Home Economics Association, Washington, D. C. 1946, p. 42.

Meat Manual, Identification, Buying, and Cooking, National Livestock and Meat Board, Chicago. 1945.

heat penetration into meat cuts. One should then select within a given time range the shortest roasting time per pound for: (1) a cut that is relatively large in size, (2) a cut that has a relatively large surface exposed to oven heat, and (3) one that has a thick layer of surface fat.

Shrinkage of meat during roasting. This aspect of meat cookery is particularly important, since with excessive shrinkage the roast becomes unattractive in appearance and loses so much juice that it is apt to be dry and lacking in flavor. Moreover, having lost portions of its nutrients, the food value of the meat becomes lessened. Finally, from an economy viewpoint, loss in weight and volume means fewer servings from a given piece of meat.

Types of losses. Types of losses from meats during shrinkage are termed: volatile losses and drippings losses.

Volatile losses include water removed from the meat due to vaporization, together with loss of any other volatile substances that were originally present in the meat or else were made, through the agency of heat, from other meat components—chiefly fats.

Drippings losses include melted fats and any water-soluble, nonvolatile substances such as soluble salts, dispersible proteins, extractives, and vitamins. This mixture of substances is carried out from the meat by way of drippings into the roasting pan.

Factors affecting shrinkage. The factors that have been found to be of influence in affecting the extent of shrinkage losses in meat are: (1) quality of the meat, especially in respect to fat content, (2) the temperature at which the meat is roasted, and (3) the degree or stage of doneness to which it is cooked.

Of these shrinkage factors, *quality* is of least significance from a cookery angle. It is inherent in the meat cut selected and is largely out of control of the cook. The same is not true, however, of *oven temperature* to which the meat is subjected and of the *degree of doneness* eventually obtained; these

factors *are* under control of the cook and careful attention to them will insure a cooked product of maximum nutritive value and maximum palatability in all respects—appearance, flavor, juiciness, and tenderness. Authoritative observations in regard to the effect of these two factors are discussed in the following paragraphs.

Effect of oven temperature. General agreement exists among authorities that *low or moderate oven temperatures cause less shrinkage of meat than do high temperatures.* High temperature roasting causes rapid coagulation of cell proteins of muscle tissues and an accompanying squeezing-out of water from within their colloidal structure. As a result, this water, carrying soluble components of inner-cellular origin, joins extra-cellular juices; and from this location, outside of the cells, these juices are more or less readily removed from the meat—some of the water by evaporation, some, carrying soluble substances along with it, by dripping out. Roasting meat at a high temperature also increases the quantities of substances, other than water, that are thereby rendered volatile, and it increases, too, the quantity of melting fats.

As a consequence, with high-temperature roasting, both volatile and drippings losses from meats are increased, hence meat shrinkage becomes correspondingly greater than when meats are subjected to more moderate roasting temperatures.

Effect of degree of doneness on meat shrinkage. As said previously, the second of the two more important factors that affect shrinkage losses in roasting meat is the degree of doneness to which it is cooked. In this respect, it must be generally obvious that, as the meat is cooked from rare, to medium, to well-done stages, losses, both volatile and drippings, must necessarily increase and shrinkage of meat become increasingly greater.

And, as a matter of fact, it is difficult to carry the cooking of meat to the well-done stage without having relatively large

shrinkage losses, since shrinkage is rendered most apparent beyond the medium stage when, with further cooking, the meat becomes drier and quite evidently lacking in juice.

Uniformity obtained when roasting meats at low temperatures. Another advantage, aside from the reduction of shrinkage, that is obtained through the roasting of meats at low temperatures is that of effecting a more uniform cooking of the meat from the surface to the center. This is evidenced by color changes that occur which can be observed in the cut slice of meat. When the cut slice is taken from meat roasted to the rare or medium stage *at low oven temperatures*, it shows a gradual change from slightly brown at the edge to brownish-red in the next layers, to red or pink in the center of the slice. This is in contrast to the appearance of the meat slice taken from the roast cooked *at high oven temperatures*, which shows a broad band of dark brown on the outer area of the slice and an abrupt change to a red or pink toward the center. In the latter roasts the meat near the surface is always at the well-done stage even in so-called rare meat.

When meat is roasted to the well-done stage, regardless of roasting temperature, it is always brown throughout, since even its central portions have reached temperatures high enough to cause the red of hemoglobin to turn to the brown of hemin.

Searing as a preliminary to roasting. It has long been the practice in roasting meat to subject it first to high oven temperatures of from 450 to 500° F. for a period of from 15 to 20 minutes, then to finish the cooking at lower temperatures ranging up to 400° F., depending upon personal experience and preference. This initial high-temperature treatment is called *searing*. Originally the procedure was thought to coagulate the proteins at the cut ends of muscle fibers sufficiently to seal them, thereby holding in the juices. But in actual fact, searing may have exactly the opposite effect in

that intensive initial heat treatment causes greater loss of juices and fats. It follows, therefore, that this procedure is open to question.

However, since searing tends to enhance the outside appearance of a roast, both the lean and fat portions, it may still be used provided the roasting process is continued *from then on* at such low temperatures as 325° F. or slightly lower. On the other hand, searing may be omitted entirely and the meat roasted at a constant oven temperature throughout the entire time. According to this method, temperatures should not exceed 350° F.

BROILING

Thus far the discussion of meat cookery has centered around roasting methods, for the reason that more research studies have been made in reference to meat cookery by roasting than by other methods. Nonetheless, *broiling* is a highly favored means for cooking certain meat cuts, such as steaks, chops, and cutlets.

This method requires holding the meat exposed to direct heat for a relatively short period of time. The usual procedure is to place the meat on the rack of a broiler pan and to expose the top surface to the flame or other heat source until this surface is brown and the desired degree of doneness has penetrated to the approximate center of the cut; this upper browned surface should then be seasoned with salt and pepper. The meat should then be turned and the broiling continued until the second surface is brown and the meat is cooked to the desired degree throughout; seasoning with salt and pepper should be repeated.

As in cooking meats by roasting, it has been found that broiling a meat cut at low rather than at high temperatures results in less shrinkage and a product of greater palatability. These low broiling temperatures are made possible by so adjusting the broiler rack that the top surface of the meat is several inches from the source of heat. For relatively thick

cuts of meat, from $1\frac{1}{2}$ to 2 inches in thickness, this distance should be about 3 inches; for relatively thin cuts, less than $1\frac{1}{2}$ inches in thickness, the distance need be only about 2 inches. Quite reasonably this arrangement provides for a longer period for heat to penetrate to the center of a thick cut of meat while its surface is acquiring the right degree of brown color, and a shorter heating period to accomplish the same ends with a thin cut.

As is true with all methods for cooking meats by dry heat, broiling to the *well-done* stage is accompanied by considerable shrinkage.

COOKING MEATS IN MOIST HEAT

Used for less tender cuts. Meats that are usually cooked by moist heat methods (p. 208) are those which are classed as less tender. They are cuts which contain relatively large amounts of connective tissue. This practice arises from the fact that by the use of moist heat, cooking times can be prolonged, thus providing time for the change of a sufficient amount of collagen to gelatin to produce the desired tendering effect. Even so, cooking time must not be prolonged to such length that so much collagen is changed to gelatin that the meat falls apart, becomes unattractive in appearance, and, if in large pieces, is difficult to carve.

Always at well-done stage. Meats cooked by moist heat should always be carried to the well-done stage. If so desired, a meat thermometer can be used if the piece of meat is large; but in some cases, as with stews, it is not possible to employ such a device. As a practical substitute one can resort to time tables that are published for cooking meats after these methods; or, better still, one can depend upon the time-honored custom of testing the meat for tenderness with a sharp-tined fork.

Cooking temperatures advised. In moist heat methods of meat cookery, temperatures used are of as much importance as in those methods which employ dry heat, since the same

principles apply. In order to avoid a hardening of muscle tissues, and accompanying shrinkage of the meat, cooking temperatures should be moderate. If the meat is covered with water, as in making stews or in cooking ham submerged in water, or if the meat is only partly covered, as in cooking pot roasts, the surrounding water should be kept at simmering temperatures of about 185° F. It should at no time reach the boiling temperature of approximately 212° F. In moist heat methods that use very small amounts of water, as in braising meat in a covered pan in the oven, the temperature of the oven should not exceed 325° F.

How enhance flavor. Flavor of meat dishes in which moist heat methods of cookery are used can be greatly enhanced by browning the meat in a small amount of hot fat before water is added. In this way, on surface areas of meat, characteristic changes are brought about in extractives, fats, and other meat components; also products are made which, dispersed in the cooking water, contribute flavor to both meat and gravy.

CURED MEATS

Purpose. Cured meats are meats which have been salted, as with corned beef; salted, smoked, and dried, as with dried beef; or salted and smoked, as with ham and bacon. Originally, curing was employed solely as a means of preserving meat for future uses (p. 296) and, toward this end, sufficiently concentrated brines were used so that meats, thus treated, would keep for a long time at ordinary temperatures. Today, however, the great popularity of cured meats is due both to desired flavors contributed by selected salts and components of the smoke, and to the variety they introduce into meal planning. Furthermore, with modern refrigeration facilities so widely available, most cured meats are kept refrigerated, a practice which has made possible milder curing procedures.

Curing mixtures. Curing mixtures can be applied to meats in various ways: (1) the dry salt mixture can be rubbed

into the meat; (2) the meat can be immersed in a solution of the mixed ingredients; or (3) the curing mixture can be "pumped," under pressure through hollow needles, directly into the veins. This last method is used extensively at the present time for the curing of hams; it has the advantage over other methods in the greater speed and more even distribution with which the curing solution diffuses throughout the tissues.

While curing mixtures vary as to components, according to the particular product desired, they always contain sodium chloride to preserve, dry, and harden the tissues (p. 296); usually they contain sugar, both for the purpose of counteracting any undue hardening effect of the salt, and for contributing flavor—as in the instance of sugar-cured hams and bacon; spices may also be included in the mixture for obvious reasons. Sodium nitrate and sodium nitrite are usually present; these salts are color-fixing agents in that they cause changes in hemoglobin whereby meat retains its red color when heated, instead of becoming brown as usually happens.

Smoking. Smoking, when used, follows the salt-curing treatment. It contributes flavor and has a slight preserving action due to the creosote component of the smoke. The particular variety of wood used, the temperature of the smoke house, and the length of the smoking period are all variable factors which affect flavor in the finished cured meat.

Tenderized ham. This product owes its tender quality to the use of higher smoking temperatures than were formerly employed. Since such ham is partially cooked during the smoking process, it requires a shorter cooking time than does one which is smoked at lower temperatures.

CARE OF MEAT IN THE HOME

Consumer's responsibility. All meats which are distributed under jurisdiction of federal and state laws (p. 203) are insured as to wholesomeness until they reach the retail markets. In these markets, municipal or other local laws

have control, and such laws, if they exist at all, vary in their strictness. The consumer's responsibility, therefore, as concerns a wholesome meat supply, begins with the patronage only of such retail shops as are kept in a sanitary condition, and then extends to the maintenance of sanitary conditions for meat storage in the home.

Recommended measures. Raw meat, with its considerable moisture, unless kept clean and cold, presents a favorable medium for growth of molds and bacteria. Consequently, as soon after purchase as possible this meat should be unwrapped, put into a clean receptacle, only *partly* covered, and then placed in a part of the refrigerator where a temperature of 45° F. or below can be maintained. If the meat is to be held for more than two days, it should be stored at a temperature lower than 45° F. Experimental evidence¹¹ shows that bacterial growth is favored if the meat container is completely covered, and that this effect is exaggerated if it is kept at temperatures above 45° F. for longer than two days.

Before starting to cook meat, it should be wiped thoroughly on all sides with a damp cloth in order to free it from adhering material. Finally, if there is left-over *cooked meat*, it should be cooled quickly to room temperature, after which it should be covered to keep it from drying out, and placed in one of the coldest parts of the refrigerator.

POSSIBLE INFECTION FROM EATING MEATS

Trichinae. Source. It has been said previously that all meat federally inspected is guaranteed to be wholesome, but there is one exception to this in the possible infection of pork with the parasite *Trichinella Spiralis*. This is a small, round worm that becomes embedded in the muscle tissues of the hog and, if such meat is ingested by humans, these para-

¹¹ Palst, A. M., "Meat keeping in home refrigerators studied in varying conditions," *Yearbook of Agriculture*, United States Department of Agriculture, 1931, pp. 369-379.

sites may eventually penetrate to body muscles, causing thereby the condition known as trichinosis.

There are no practical means for determining the presence of trichinae in pork muscle since they are detected only by microscopic examination, and, obviously, all of the tissues from any hog cannot be subjected to such scrutiny.

Destroyed by heat. Fortunately, however, these parasites are destroyed by heat; therefore their presence in raw pork need not be a serious matter *if pork is always cooked to the well-done stage*. To attain this well-done condition, a temperature of 185° F. must penetrate even to the center of the meat, a measure which provides for a margin of safety because trichinae are destroyed at 137° F.

Federal meat inspection for pork products. For all pork products which are customarily served with little or no cooking, such as salami, bologna, and frankfurters, Federal Meat Inspection requires special processing during manufacture in order to insure the destruction of all trichinae that may be present. This processing may involve: (1) lethal heat treatment, or (2) freezing long enough to destroy these organisms, or (3) a curing process by other specified and effective methods.

Ptomaines. This is a term frequently and loosely applied to food poisonings that may arise from consumption of any spoiled foods, including meat. But, correctly speaking, ptomaines is the name applied to a class of compounds that result from chemical changes involving certain amino acids (p. 136) in which bacteria function. These ptomaines may or may not be poisonous, but all are malodorous. They are present only in meat that has reached an advanced stage of spoilage, indeed so far advanced that the meat would hardly be used as food. It is obvious, therefore, that food poisoning from actual ptomaines rarely, if ever, occurs.

When poisoning from ingested food does occur, it is frequently traced by experts to the presence of certain bacteria which produce toxic substances and which have gained en-

trance to the food as the result of careless and insanitary handling by someone immediately concerned with food preparation.

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CHAPTER XVI

GELATIN

Source and preparation. Gelatin is obtained from any of the tissues of meat animals that contain *collagen* as a component. These tissues include the connective tissues of cartilage, tendons, and bones; they also include skins, hoofs, and horns. Upon subjecting any of these to a series of preliminary treatments, which vary somewhat according to the particular tissue concerned, a dispersion of collagen in water is obtained. And when this dispersion is heated just below boiling temperature for several hours—provided the dispersion is maintained at either a distinctly acid or a slightly alkaline reaction—the collagen is changed to gelatin.¹ Finally the water is evaporated, leaving the gelatin in the form of sheets. These are dried in currents of hot air, and the gelatin sheets are then either broken into small pieces or are finely granulated. The latter form is the usual one for use in cookery.

Food value. Gelatin is a protein which belongs to the albuminoid (p. 383) class of simple proteins. From a nutritional viewpoint it is an incomplete protein (p. 137). Consequently, although a good food, gelatin should not be depended upon for the sole source of protein in the diet.

Uses and properties concerned. As said previously, gelatin forms a colloidal dispersion in water. This disper-

¹ Bogue, R. H., "Conditions affecting hydrolysis of collagen to gelatin," *Industrial and Engineering Chemistry*, Vol. 15 (1923), pp. 1154-1159.

sion can be either sol or gel² in character depending upon the proportion of gelatin to water and upon the temperature of the dispersion. In sufficient concentration a gelatin dispersion which is a *sol* at high temperatures forms—as it is cooled—a *gel* structure in which the gelatin, because of its ability to adsorb (p. 370) considerable quantities of water, occupies many times its original volume. It is to this property that the chief importance of gelatin in food preparations is due, since food materials of many flavors that may have been introduced—fruit and vegetable juices, flavored milk, etc.—become captured in permanent dispersion within the gel structure (p. 225) as the gelatin sol, upon cooling, sets to a gel.

But gelatin in *sol* dispersion also has significant food uses. When such a sol in low concentration is present in a sugar solution in which crystallization of sugar is beginning to take place, as in the making of certain candies, the gelatin concentrates at the surfaces of the small sugar crystals to prevent their aggregation into large crystals (p. 39). Or when a gelatin sol is present in a mixture that is impregnated with gas bubbles, such as a whipped dessert, the gelatin concentrates at the surfaces of gas bubbles to prevent their coalescence, thereby lengthening the life of the foam (p. 371).

Preparation of gelatin dishes taking advantage of gel formation. In using gelatin for preparation of dishes to which gelatin in *gel* dispersion is essential, it is first allowed to stand for several minutes in a small amount of cold water—approximately 4 tablespoonfuls of water to 1 tablespoonful of granular gelatin—until the gelatin becomes hydrated; when this condition is obtained, the mass looks translucent throughout. At this stage the dispersion may be heated, or, more usually, hot water is added to it. In either case, in hot water the hydrated gelatin forms a colloidal sol. However, for food uses, instead of adding just hot water to bring about the sol dispersion, it is the usual practice to introduce a hot

² *Sol* refers to a colloidal dispersion which is *fluid*.

Gel refers to such a dispersion which is *jelly-like*.

fruit or vegetable juice, or hot milk or custard, toward achieving a flavorful product. The *sol* is then poured into a mold and allowed to chill, in order to promote its setting to a colloidal *gel*.

The length of time that is required for "setting" is influenced by several factors, the most important of which are: (1) concentration of gelatin and (2) degree of cold. With an increase in either one or both of these factors, the time of setting is shortened. It is important, however, to avoid too great a concentration of gelatin in an unwise attempt to shorten the time for "setting," since in that case the final molded product will be too stiff to be palatable. An average proportion is 1 tablespoonful of gelatin to 1 pint of liquid.

Structure of gelatin gels. The exact process which takes place, when a gelatin sol sets to a gel, and the structure of the gel, when it becomes established, are open questions at the present time. The consensus of opinion seems to be that, upon cooling, the highly hydrated molecule aggregates, or micelles, of gelatin become associated in the form of an intertwined mesh, which encloses the liquid in such a way that the entire mass seems rigid. The outward manifestations of this process are: (1) a progressive increase in viscosity of the dispersion from sol to gel stages and (2) the final setting of the gel to a consistency that renders a mold possible.

Types of gelatin dishes. The gelatin sol in setting to a gel upon cooling is such an adaptable dispersion that, by changing cookery technics, many types of dishes can be prepared through its use. These dishes range from clear, transparent gels, such as a tomato gelatin salad and orange or lemon jelly, to a foam type of dessert such as Spanish cream or snow pudding.

Clear gelatin mixtures. When desired, solid pieces may be incorporated by mixing them with the gelatin sol after it has cooled slightly and become viscous enough to hold the pieces suspended throughout the whole mass. Or this technic can be altered and the solid pieces arranged in an orderly

pattern, by surrounding each layer of distributed solid pieces in the mold with gelatin sol, and allowing this to set before superimposing the next layer of solid pieces with its enveloping gelatin sol.

A foam type of dessert, usually called a *sponge*, is prepared by beating the sol to incorporate air bubbles just before it sets and is still viscous. In such a system, the gelatin acts as a stabilizing agent for the dispersion of air bubbles in gelatin sol, until such time as the gel forms and holds the dispersed air firmly in place. Beaten egg white, whipped cream, or both can be incorporated into the gelatin sol at the viscous stage to prepare desserts like snow pudding and fruit charlottes. In these desserts, the molded product is sponge-like throughout. A layered effect, such as is characteristic of Spanish cream, is obtained by incorporating beaten egg white into the sol before it becomes viscous. In this instance, the egg foam, because of its lower specific gravity, rises to the top of the sol, where it is held in place by the "setting" gel dispersion.

These are only a few of the food preparations in which gelatin can be utilized in similar ways and which are not only excellent in food values but are aesthetically satisfying in appearance and flavor.

Precautions. A gelatin sol which is highly acid, such as a lemon jelly, must not be kept for long at a near-boiling temperature, since hydrolysis of the gelatin may occur and its ability to form a gel may thus become impaired.

Also, raw pineapple should not be used in preparing gelatin mixtures since this fruit contains bromelin, a proteolytic enzyme, which catalyzes the hydrolysis of gelatin, thereby rendering the gel formation impossible. But either canned or cooked pineapple can be used for such purpose, since, during the processing, bromelin is destroyed.

CHAPTER XVII

FISH

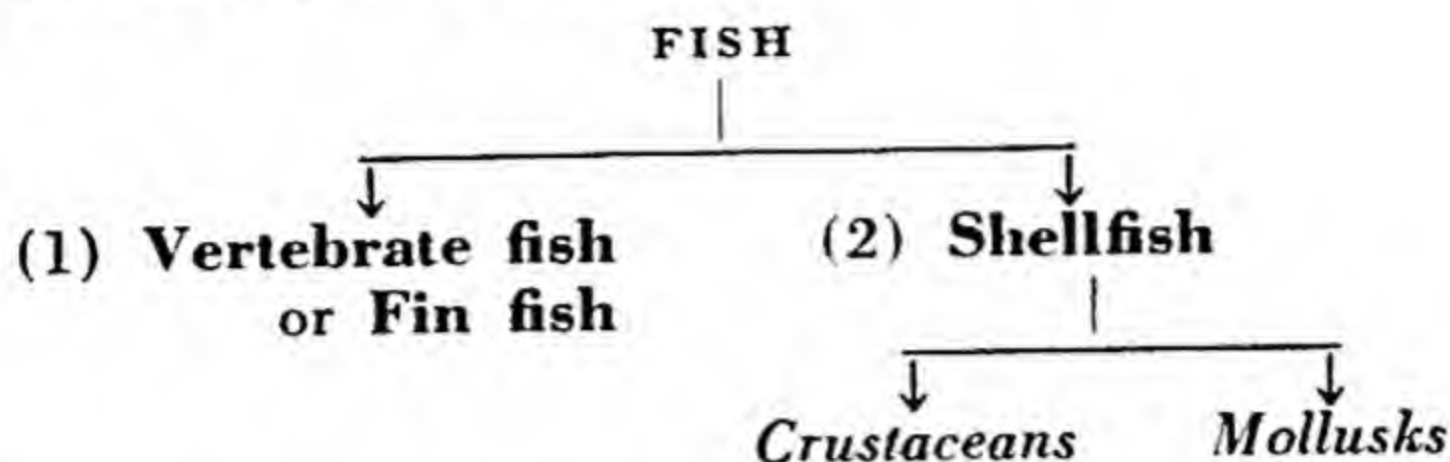
Sources of fish. Every year several billion pounds of fish are taken from the surrounding seas and inland waters of the North American continent. The work connected with catching and handling them has, in recent years, brought a return to fishermen which, in monetary value, exceeds 200 million dollars.

From coastal areas. From Newfoundland southward along the Atlantic coast, in the Gulf of Mexico, up along the Pacific coast and north to include Alaska, many different kinds of fish abound. But in these coastal areas the important fishing centers are located: (1) in the shallow waters of the shore and in rivers where the fish go each year up from the sea to spawn, and (2) in the shallow-water areas, called *banks*, that lie short distances off the coastline. On these banks fish congregate in large numbers in order to feed upon the many kinds of small plants and minute animals—called plankton—that abound in these relatively shallow waters.

Varieties. Haddock, cod, mackerel, flounder, and herring are the leading varieties of fish caught in the North Atlantic fishing grounds. Salmon take the lead among fish found off the Pacific coast of the United States and Canada and in Alaska. Shellfish of various kinds abound in the South Atlantic and Gulf state areas.

From inland waters. Supplementing these ocean fishing grounds, the inland lakes and rivers of the country provide important quantities of fish of many different varieties.

Classes of fish. There are two main classes into which fish may be grouped, as follows:



As the name implies, *vertebrate fish*, illustrated by cod, mackerel, and salmon, have a backbone and fins. *Shellfish* are devoid of these structures but have bodies more or less completely covered with a shell. Differentiating features between crustaceans and mollusks are: *crustaceans*, to which class the lobster and crab belong, have hard shells over the back portions of the body and over the claws, but softer shells for protection of the under parts of the body and legs; *mollusks* have two shells of the same size and shape, usually hard, which are ordinarily held tightly closed. Clams, oysters, and scallops are examples of the mollusk shellfish.

Components and food value. The nutrient components that are provided by their flesh vary so greatly in quantity among the different varieties of fish, and even among those of the same variety at different seasons of the year, that any definite statement of average composition would be far from accurate.

It is true, however, that aside from water, *protein* is the component that usually occurs in largest amounts, ranging in the neighborhood of from 15 to 20 per cent by weight of the flesh of fish. Although *nutritive qualities* of fish proteins have not been studied as extensively as have those of meat, the proteins from these two sources are generally considered sufficiently comparable as to make the use of fish in menu-planning a satisfactory meat alternate.

The most marked difference in foodstuffs among fish of different varieties lies in the *fat* component of the flesh, which

ranges all the way from less than 1 per cent to 20 per cent or more. In fact, one sometimes finds fish classified according to fat content into: (1) those which have very little fat distributed throughout their flesh, such as cod, haddock, perch, and flounder; (2) those with medium amounts of fat, such as halibut, bluefish, and herring; and (3) those with large amounts of fat, as is true of salmon and shad.

In general, the flesh of fish is *devoid of carbohydrate*. Shellfish, however, are exceptions, since there are appreciable amounts of *glycogen* in the muscles that control the opening and closing of their valvular shells.

Mineral elements, combined within the compounds concerned, comprise from 1 to $1\frac{1}{2}$ per cent of the flesh of fish. Among these food nutrients *iodine* is of special significance since compounds containing it are necessary for proper functioning of the thyroid gland, and fish taken from the *sea* are the largest single contributors to the diet of substances which contain this element. Compounds of *calcium*, of *magnesium*, and of *phosphorus* are widely distributed in fish of all kinds; and fish, especially oysters and shrimps, provide important amounts of substances which contain *iron* and *copper*.

With respect to *vitamins* the flesh of fish contains fair amounts of *thiamine* and *riboflavin* and some *niacin*; and, whenever there is appreciable fat distributed throughout the flesh, it also contributes limited amounts of *vitamins A* and *D*. However, these latter vitamins are concentrated in the fat of fish livers, with the result that fish-liver oils take leading place as sources of these two vital nutrients. But the livers are not commonly included in fish used as food.

Selection of fish. Standards of freshness. Fish is a food that deteriorates very quickly unless handled with great care. Modern methods employed in all aspects of the fishing industry have been so perfected as to insure that a high-quality, sanitary product will reach retail markets. In these final markets conditions of display differ among stores; but the *only safe practice* for storing fish is one in which they are

kept either embedded or entirely surrounded with chopped ice so that they will be held at near freezing temperatures.

It follows that when buying fish from these markets, since dependence cannot always be placed upon finding favorable storage conditions, the purchaser should be able to recognize characteristics that indicate freshness of product. Some of these are as follows: *For vertebrate fish*, the gills should be bright red, the eyes clear, bright, and slightly bulging, the flesh should be firm and, when pressed with the finger, sufficiently elastic to spring back into place. *For shellfish*, those such as lobsters and crabs should be alive when purchased, shrimps should have firm, not flabby, bodies; oysters, clams, and the like should be alive and their shells tightly closed, or if relaxed they should close when the fish is handled. Always the odor of fish should be fresh with no suggestion of putrefaction.

Cuts of fish. Occasionally fish is purchased whole, just as it comes from the water. But the more usual practice is to buy either *drawn fish*, in which case just the entrails have been removed, or *dressed fish* with entrails, head, tail, and fins removed. If desired, dressed fish may be split open and the backbone removed, or the backbone and all other bones. Also, dressed fish may be cut into *fillets*, which are the sides of fish cut away from the backbone, with the skin usually removed. If it is a large fish, such as halibut, swordfish, larger salmon, or cod, the dressed fish is cut in crosswise slices known as *steaks*.

Care in the home. For use in the home, it is important that fish be purchased on the same day in which it is to be used. When received there it should be cleaned immediately and placed, loosely covered, in the coldest part of the refrigerator until time for cooking.

Fish cookery. Because of their relatively high protein content, as well as fair offering in mineral nutrients and vitamins, fish can well be used interchangeably with meat, eggs, or cheese, as the main dish in a meal. Furthermore, because

of their many different varieties and the many attractive ways in which they can be cooked, the frequent use of fish as the main dish makes possible considerable diversity in menu-planning.

Medium-sized fish can be dressed, then stuffed and baked, or they can be split open and broiled. Small fish, fillets, and steaks are well suited to broiling, or they can be sautéed. Fillets and steaks can also be steamed or boiled. Fillets and many of the shellfish, including oysters, scallops, and shrimps, are frequently breaded and fried in deep fat. These are simple methods of fish cookery; for more elaborate procedures one may consult standard cook books. Pamphlets on fish cookery are published in various parts of the country; they are of interest in that they describe local species of fish and give recipes especially adapted to their use.

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CHAPTER XVIII

VEGETABLES

Nature has endowed all plants with the ability to take from air and soil more or less simple inorganic materials for manufacture into organic food nutrients, which include carbohydrates, proteins, fats, and vitamins. Plants use these nutrients either for building their own tissues or for functioning in other important ways that are concerned with their life processes; or they store selected nutrients in various parts of their structure as a reserve food supply for future use toward meeting vital needs. Animals, including man, benefit by nature's efficiency in this respect in that they use plants for supplying themselves with a considerable portion of the plant-made nutrients which they must have for building their own tissues and for carrying on their life activities.

In their use as food for humans, edible plants, or parts of plants, fall into two classes of food materials which are called *vegetables* and *fruits*. Since there are many varieties of vegetables and fruits in each class, and since practically all of the structural parts of many plants—more especially of many vegetables—are edible and have food value, it is not surprising that a great array of vegetables and fruits have come to be used for food purposes.

The present chapter is concerned solely with a discussion of vegetables, their food uses, and their cookery. A discussion of fruits will be found in Chapter XIX.

Classification of vegetables. *According to botanical family relationships.* From a botanical viewpoint, vege-

tables are classified according to families, obviously with all vegetables in the same family having some outstanding characteristics in common. Although, in most instances, the family to which a vegetable belongs is of minor concern in food studies, there are some exceptions; these include vegetables from plants that belong to the legume, to the mustard, and to the goosefoot families. Some plant members of these families and vegetables obtained from them are considered briefly in the following.

Vegetables from the legume family. Botanically speaking, legumes belong to the leguminosae, pulse, or pea family. They include lentils, peanuts, and the many varieties of beans. Plants which are members of this family are all characterized by the fruit, which consists of a pod composed of two parts, with seeds enclosed and fastened in a row along one of the edges where the two parts of the pod meet. When the fruit is fully ripe, the pod opens and drops the seeds. This type of fruit is known as a legume, which accounts both for the name that is applied to the family of plants producing it and for the term legume as applied to vegetables, such as peas and beans, that are obtained from these plants. Seeds separated from the pod are used for food either in the immature or "green" stage of ripeness, or in the completely ripened stage. When used as a green vegetable, green peas, for example, the pods carrying seeds are picked from the vines at the desired stage of unripeness. For use when ripe, the seeds are allowed to mature on the plant and become dry, when they are removed from the seed pods and used as dried legumes; baked beans are an example of this use.

Legumes are especially rich in carbohydrate and, for vegetables, they are outstandingly rich in proteins. Dried legumes have a higher percentage of these foodstuffs than green legumes, the chief reason being that the latter include a high percentage of water.

Vegetables from the mustard family. Among vegetables of this family are cabbage, kale, cauliflower, turnip, rutabaga,

Brussels sprouts, and broccoli. Their components include a glucoside, called sinigrin, which is a compound composed of glucose in combination with a sulfur-containing radical. During the cooking of such vegetables, especially if the time is unnecessarily prolonged, the glucoside hydrolyzes to yield glucose and the sulfur-containing compound that is unpleasant in odor and taste. It is for this reason that members of this family are often designated as strong-flavored vegetables.

Vegetables of the goosefoot family. Beets, chard, and spinach belong to this family. Vegetables of this origin are distinguished because their leaves, which are extensively used as "greens," are relatively high in oxalic acid and salts of this acid. Prominent among oxalate components of spinach is calcium oxalate, which, being an insoluble salt, cannot be absorbed from the intestinal tract, and is therefore unavailable for use in the body.

According to parts of plants represented. From the viewpoint of menu-planning, when both nutritive and aesthetic values should be considered, the more useful way of classifying vegetables is according to the part of the plant from which they are obtained. According to this method, vegetables fall into eight classes as follows: (1) *root vegetables*, exemplified by the carrot, beet, parsnip, and turnip; (2) *tubers*, which are either enlarged underground stems, such as the white potato, or tuber-like roots, such as the sweet potato; (3) *bulbs*, which include the onion, garlic, and leek; (4) *leafy vegetables*, such as cabbage, lettuce, kale, and spinach; (5) *stems*, such as asparagus and rhubarb; (6) *flowers*, among which are cauliflower and broccoli; (7) *fruit vegetables*, which include the tomato, squash, cucumber, and eggplant; and (8) *seeds*, such as corn, peas, and beans.

Vegetables from all structural parts of plants contain practically all of the nutrients that are present in the parent plants as wholes. At the same time, any given nutrient—carbohydrate or mineral constituent or vitamin—varies in amounts that are provided by different structural parts of the same

plant, whether root or leaf, etc. Any nutrient varies, too, among vegetables that are derived from the same structural part of different plants, that is, according to whether the vegetable is the root of the carrot or the beet, or the leaves of the spinach or chard, etc.

Vegetable selections in meal planning. It follows that the person responsible for meal planning should have full knowledge of these nutritive relationships among vegetables, and, in planning meals, should select vegetables to be used in direct relationship both to the food values of other vegetables and of other kinds of foods to be served at the same time. Knowledge of common class characteristics of vegetables—both on botanical and structural basis—is also of importance in meal planning because of the aesthetics concerned. Both kale and turnip, for example, or carrots and beets served at the same time would not be aesthetically appealing. The former, both of the mustard family, are apt to be strong in flavor, the latter, both root vegetables, are quite similar in texture and shape. Naturally, there are exceptions to this rule for avoiding the use of two vegetables of the same class in the same meal. These exceptions would include instances in which the vegetables concerned are different in some characteristic, such as texture, color, or flavor.

Components of vegetables. Foodstuffs present. Save for those which are dried, such as dried legumes, vegetables, as a class, have a high *water* content which ranges from approximately 70 to 95 per cent. Of the other foodstuffs present in vegetables, *carbohydrates* rank first in quantity, with the kind of carbohydrate which is in predominance—whether *cellulose*, *pectic substances*, *starch*, or *sugars*—depending in some cases upon the structural part of the plant from which the vegetable is obtained, and in others upon its degree of maturity—whether unripe or ripe. *Proteins* are present in vegetables to a lesser extent than carbohydrates; and *fats* are present only in negligible amounts. Finally, and of great importance, the quantities of *mineral*

salts and *vitamins* that are provided by vegetables are relatively large as compared with amounts obtained from many other food materials.

It has been said that the various food nutrients are distributed more or less generally throughout any given plant. But there are instances in which vegetables from specific structural parts of plants, or from parts of plants in different degrees of maturity, have definite significance as to the specific foodstuffs occurring in them. Some examples are as follows:

If the vegetable is from the stem or leaf of a plant, a large portion of the solid material is cellulose: celery and cabbage are among these vegetables. If the vegetable is a mature seed, such as fully ripe beans, or if it is a mature underground stem intended for storage, such as the white potato, its solid portion is very largely starch. Vegetables that are used when immature and succulent, as is true of green peas, carrots, onions, and beets, still retain considerable of the plant sap, hence they are more or less rich in sugars. Mention has already been made of the high protein content of legumes.

Although all vegetables are important sources of mineral salts and vitamins, green and yellow vegetables and green leafy vegetables probably take first place, especially as regards carotene (provitamin A), riboflavin, ascorbic acid, and the element iron. Young stems, such as asparagus and certain of the fruit vegetables including the tomato, also deserve mention in these respects.

Non-foodstuffs. Accompanying the nutrient components of vegetables, certain other materials are present which have little or no food value but are of great concern in vegetable cookery because of their effect upon flavor, color, and general palatability of the cooked product. These materials include: (1) flavoring substances, (2) plant pigments, and (3) tannins.

Flavoring substances. *Organic acids.* Many organic acids (p. 345) occur in vegetables. Some are volatile, some nonvolatile, but all contribute flavor and, to a very small extent, food value.

Volatile aromatic oils. But the components of vegetables which are chiefly responsible for their characteristic flavors and odors are volatile aromatic oils, which are already present in some vegetables when raw, but appear in other vegetables only when cooked. Thus, a flavorful volatile oil occurs in *raw* onions, garlic, and other vegetables that belong to this botanical family. On the other hand, with *raw* vegetables from the mustard family, such as cauliflower and cabbage, the odor of the glucoside sinigrin is not noticeable; but, *during cooking*, sinigrin is hydrolyzed to glucose and a volatile oil of pungent odor commonly called mustard oil. The hydrolysis of sinigrin is catalyzed both by an enzyme provided in the vegetable itself and by the various plant acids.

Pigments. The attractive and varied colors of vegetables are due to the presence of pigments distributed in plant tissues. There are many individual pigments, but according to their chemical constitution they are: (1) chlorophyll, or (2) carotinoid, (3) flavone, or (4) anthocyanin pigments.

Chlorophyll is the characteristic green pigment that is so widely distributed in plants. It is dissolved in the fat-like substances (p. 380) that occur in leaves and other green parts of plants. The chief interest in chlorophyll from a cookery viewpoint is that, when heated in an acid solution, the pigment is changed to a brown-colored compound called phaeophytin. In an alkaline medium the original green shade of chlorophyll is greatly intensified.

Carotinoid pigments are red, yellow, or orange in color. Like chlorophyll they are dissolved in the fat-like substances of the plant; but, in any tissue in which both carotinoid pigments and chlorophyll are present, the green color of the chlorophyll usually predominates and masks the yellow color of the carotinoid pigments. Carotinoid pigments, when alone, impart the yellow or orange color to such vegetables as carrots and sweet potatoes, and the red color to tomatoes. The outstanding importance of these pigments lies in the fact that among their members are alpha- and beta-carotene and cryptoxanthin, all of which pigments are con-

verted to vitamin A in the animal body; hence the origin of the dietary rule: "Include in the diet every day at least one serving of a green or yellow vegetable." Conditions encountered in cookery procedures do not influence the color of these pigments.

Flavone pigments are distributed in the cell sap of plants since, unlike chlorophyll and carotinoid pigments, they are soluble in water. The color of flavone pigments is influenced by the reaction of their environment. When in an acid environment these pigments are practically colorless, but they become increasingly yellow in color as the medium becomes neutral and then alkaline in reaction.

Flavone pigments occur in such vegetables as cauliflower, onions, white cabbage, and potatoes. They are responsible for the yellow shade that is often acquired by these vegetables when they are cooked in hard water (water that contains soluble calcium salts which render the medium slightly alkaline in reaction).

Anthocyanin pigments are red pigments which are widely distributed in fruits and flowers and are found in a few vegetables such as radishes, red cabbage, red onions, and beets. Like the flavones they are cell-sap pigments and therefore are water-soluble. They resemble flavone pigments also in the fact that their color is influenced by the reaction of their environment. In an acid medium they are red in color, with decreasing acid concentrations they become purple, and finally as the medium becomes alkaline they are blue.


Since in some vegetables both flavone and anthocyanin pigments are present, the yellow of the flavone pigment and the blue of the anthocyanin pigment tend to impart a green color to such vegetables when the cooking medium is alkaline.

Tannins are complex organic compounds that are rather widely distributed in plants. They are slightly soluble in hot water and the solution formed has an astringent quality. Contact between tannins and ferric salts results in the formation of greenish-purple compounds which, upon oxidation,

turn brown. These reactions are encountered whenever a tannin-containing, slightly acid vegetable, such as cabbage, is cut with an iron knife blade so that an iron salt is made. This explains, at least in part, the discoloration of the cut surfaces of certain vegetables.

Tannins react with proteins to make insoluble compounds, which accounts for the fact that when milk is heated with vegetables which have a relatively high tannin content, such as peas, asparagus, and potato, a curdling frequently occurs.

VEGETABLE COOKERY

 **Objects and methods.** Vegetables such as salad greens and many of the fruit vegetables are customarily served raw, but other vegetables, as a rule, are subjected to cooking procedures. The cooking serves various purposes: the cellulose of the structural framework is softened, hence the vegetable loses its rigidity and becomes more tender; the physical condition of starches is altered so that they are rendered more available for speedy digestion; flavors are modified, as the result of which many vegetables are made more appealing; and, finally, various ways of cooking increase the number of vegetable dishes that are possible, thus lending variety and interest to daily menus.

In general, vegetables may be baked or sautéed, they may be boiled or steamed; they may be served with butter or covered with an appropriate sauce; or, after being boiled or steamed, they may be creamed, mashed, or sautéed. For detailed directions in regard to simple methods for cooking specific vegetables and for elaboration of these methods, one should consult cook books.

Effect of cooking vegetables upon structural framework. (The more or less rigid structure of vegetables in the raw state is due to the presence of certain resistant components of the containing walls of the myriads of cells, both those that make up the supporting framework of plants and those that contribute to the softer tissues. Cellulose predominates

among these materials but pectic substances (p. 332), chiefly protopectin, are also present; and protopectin, like cellulose, is nondispersible in water. Also, in addition to contributing to cell walls, protopectin is distributed between cells of plant tissues where it plays a cementing role which imparts further rigidity.

At the high temperatures that prevail during cooking of a vegetable, a partial disintegration of cellulose may occur and hydrolysis of protopectin takes place to produce substances that are water-dispersible.¹ As a result, the structural framework of the vegetable becomes thinner and its supporting effect is correspondingly diminished; also, with the decrease in protopectin between cells, the tissues tend to soften throughout. With extended heating these changes are, of course, progressive, and are accompanied by a continually increasing loss in the rigidity and crispness that are characteristic of the raw vegetable. These changes should be continued only until the vegetable has acquired the desired degree of doneness; if carried beyond this point the product becomes so soft and so lacking in structure as to be unpalatable.

Effect of cooking on starch and proteins. As the structural parts of a vegetable become softened during the cooking process, water begins to penetrate the cells. As a result, starch granules located within the cells become gelatinized (p. 45); this change is a digestive asset since gelatinized starch is more dispersible with digestive juices than is the raw starch of uncooked vegetables.

During the cooking process the proteins of a vegetable undergo a slight alteration, possibly hydrolytic, which may be regarded as an initial step in protein digestion.

Vegetable cookery and flavor. When vegetables, such as lettuce and other greens, are served raw, their natural flavors are preserved. For greatest attractiveness these vege-

¹ Simpson, J., and Halliday, E. G., "Chemical and histological studies of the disintegration of cell-membrane materials in vegetables during cooking," *Food Research*, Vol. 6 (1941), pp. 189-206.

tables should be prepared some time in advance of serving; a procedure which should include a thorough washing in cold water, and, with some water still clinging to them, a thorough chilling in the refrigerator in order to produce an attractive crispness. Finally, just before serving, the vegetables should be patted with a dry towel in order to remove the clinging moisture.

On the other hand, when vegetables are cooked, certain flavor changes occur which vary with particular vegetables and with methods of cooking employed. Specific instances and cooking technics to be observed are as follows:

No sugars should be lost. In cooking vegetables, care should be taken to lose none of the original sweetness due, of course, to the presence of one or more sugars. In another section of this chapter (p. 247) technics are presented for avoiding any extensive leaching out from the vegetables of soluble mineral salts and soluble vitamins into the water in which they are cooked; and the same technics can be observed for preventing any considerable loss of sugars.

Cooking strong-flavored vegetables. In cooking so-called strong-flavored vegetables, such as onions and members of the mustard family, which include cabbage, cauliflower, turnip, etc., it is important that precautionary measures be observed toward securing a cooked vegetable that will have an acceptable flavor. And the cooking method selected must depend to quite an extent upon whether the aromatic oil (p. 237), which gives rise to the flavor, is already present in the free state in the raw vegetable, or whether it is combined within a glucoside. Examples are as follows:

Since the flavorful, volatile oil is present in the free state in raw onions, if a product is desired which is mild in flavor, this vegetable should be cooked in a relatively large quantity of boiling water and in an open utensil. During this procedure, considerable portions of the strong-flavored, volatile, aromatic oil pass off with the steam. However, should one prefer to retain in the cooked onions the stronger flavor that is charac-

teristic of raw onions, then they should be boiled in a small quantity of water in a covered utensil.

With vegetables such as cabbage, in which the volatile oil is held in combination within the glucoside sinigrin (p. 234), if a cooked product mild in flavor is desired, the cooking procedure should be such as to avoid any extensive hydrolysis of the glucoside and accompanying liberation of the substance which is responsible for the strong flavor. Two such procedures are as follows:

1. The vegetable can be cut into small pieces and cooked in a small amount of boiling water in a covered utensil. Due to a rapid penetration of heat into the vegetable in the early stage of cooking, the enzyme which favors the reaction is destroyed before very much hydrolysis has taken place, hence before very much of the objectionable flavored product has been made.

2. Or the vegetable, whole or in large pieces, can be cooked in a relatively large quantity of boiling water and in an open kettle. After this procedure, although there is a delay in the destruction of the enzyme, the larger quantity of water dilutes the plant acids sufficiently so that their (the acids) catalyzing effect upon the reaction is checked. Furthermore, the open utensil allows for the escape of any volatile acids present and some of the volatile aromatic oil that is produced from the sinigrin hydrolysis.

While a vegetable cooked according to the latter method is usually more mild in flavor than when cooked after the first procedure described, it will undoubtedly have suffered a greater loss in water-soluble nutrients (p. 247).

Vegetable cookery and color changes. *Cooking of green vegetables.* Green vegetables probably present the greatest problem in cooking. When in plants, the chlorophyll, dissolved in fat-like substances, is in a neutral environment, hence the maintenance in the plants of their green color. But during cooking, as the structural and supporting frame

work of the vegetable disintegrates, plant acids and the green pigment, previously separated from each other, becoming released, are to a less or greater extent brought into contact, hence the change of the green to brown begins. The cooking procedure, therefore, should be such as will either keep this contact to a minimum or will reduce the acidity of the environment. Which procedure is used depends upon whether the vegetable concerned is mild or strong in flavor. Thus:

If the vegetable is mild flavored, such as peas, lima beans, green snapbeans, asparagus, or spinach, it should be cooked in as short a time as possible in a small amount of cooking water and in a covered utensil. Also the vegetable should be served as soon as it is done. These procedures assure a minimum of time during which the chlorophyll and acids remain in contact with each other before the vegetable is used. A pressure saucepan, as cooking utensil, serves admirably by way of shortening the cooking period that is necessary to bring the vegetable to the desired degree of doneness.

If the green vegetable is of the strong-flavored type, such as kale, Brussels sprouts, turnip greens, and the like, an alternative method calls for cooking the vegetable in a relatively large quantity of boiling water in an uncovered utensil. By this means, the vegetable acids in contact with chlorophyll are kept at a low concentration, due both to their dilution with the large volume of water employed and to the removal with the steam of those acids that are volatile. Hence, in this instance, it is the keeping of acids that are in contact with chlorophyll in low concentration that tends to preserve the green color of this pigment. Vegetables cooked according to this method should also be served immediately.

Cooking of red and white vegetables. Vegetables which carry *red pigments of the anthocyanin class* (p. 238), after the order of beets and red cabbage, and those which carry *white flavone pigments*, such as white cabbage and cauliflower, retain their natural colors in an acid environment. Therefore, fortunately, as these vegetables are cooked in boil-

ing water, some of their acids seep into this water to create the environment that has a favorable effect on the retention of their red and white pigments. However, if for any reason conditions should be such as to cause neutralization of these acids, to the extent that the cooking water tends toward a neutral or even an alkaline reaction, the white pigment becomes yellow and the red of these vegetables begins to change to a blue color.

Effect of cooking in hard water. This neutralization of acids can happen when hard water is used for cooking as is customary in many localities. To offset this condition a little lemon juice or vinegar or even slices of sour apples can be added to the cooking water in order to maintain its acid reaction (p. 256).

Cooking of vegetables with carotinoid pigments. As stressed previously, these pigments are yellow, orange, and red, and representative vegetables which contain them are carrots, sweet potatoes, yellow turnips, and tomatoes. But since the color of carotinoid pigments is not affected by either an acid or an alkaline environment, the cooking of vegetables containing these pigments does not present a problem.

Conserving food values. Emphasis has already been given to the fact that the important and unique nutritive contributions of vegetables to the diet are the mineral salts and vitamins which they contain. Most of these salts are water-soluble; some vitamins also are water-soluble, and some vitamins are not only water-soluble but are destroyed by heat or by oxidation.

Therefore, it becomes a matter of concern to employ cookery procedures for vegetables: (1) which will avoid, insofar as is possible, the loss of minerals and vitamins *by solution* in accompanying water; and (2) which will control the *amount of heat* used and the *contact of vegetable with oxygen* during the cooking process in order to reduce vitamin losses to a minimum. But to what extent these losses do take place

and what cookery procedures will produce a cooked vegetable, approximately equal in food value to the raw vegetable, has called for considerable research.

Data arising from such researches, with which workers in this field are in general agreement at the present time, are presented in the following discussions.²

Reducing losses from destruction of vitamins. Carotene and thiamine. It is quite generally agreed that carot-
inoid pigments (provitamin A) are not affected by heat to any significant extent; therefore vegetables such as green and yellow ones, that are important sources of vitamin A, are about equal in value as to this vitamin in the cooked state as when raw.³ Thiamine is also found to be fairly stable toward heat as it is applied in ordinary processes for cooking vegetables.⁴ The stability of thiamine is increased in an acid environment.

Ascorbic acid. But with ascorbic acid the situation is quite different. This vitamin is apparently destroyed upon oxidation, through a reaction that is catalyzed by an oxidizing enzyme already present in the plant tissue; the oxidizing reaction takes place at room temperature and is accelerated with increasing temperatures until this enzyme is destroyed. Factors other than enzyme catalysis probably cause destruction

² Inasmuch as new knowledge is constantly being accumulated on this subject, the student is strongly advised to keep in touch with current scientific literature in which new findings are reported.

³ Gleim, E. G., Tressler, D. K., and Fenton, F., "Ascorbic acid, thiamine, riboflavin, and carotene contents of asparagus and spinach in the fresh, stored and frozen states both before and after cooking," *Food Research*, Vol. 9 (1944), pp. 471-490.

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⁴ Gleim, E. G., Tressler, D. K., and Fenton, F., *op. cit.*, pp. 471-490.

Mayfield, H. L., and Richardson, J. E., *The vitamin content of green string-beans when cooked or canned and stored*, Montana Agricultural Experiment Station, Bulletin No. 373 (1939).

of ascorbic acid, since it is known that, as long as the vegetable remains hot, this process continues to some extent even after the enzyme has been destroyed. Fortunately, as with thiamine, ascorbic acid is able to offer some resistance to these destructive influences as long as it is held in the presence of the acid environment that is provided by the plant acids themselves.

With these properties of ascorbic acid in mind, the measures which should be observed in vegetable cookery in order to avoid its destruction as much as is possible are as follows: *First*, the vegetable should be subjected to a rapid increase in temperature during the first few minutes of cooking in order to destroy the enzyme which favors the oxidation of this vitamin. *Second*, too long a period of cooking should be avoided, in order that the effect of other destructive factors as to ascorbic acid may be held at a minimum. *Third*, the presence of plant acids should be retained as far as possible in order to offset these destructive influences.⁵

Accordingly, *for conservation of ascorbic acid*:

1. The vegetable should be placed in a small amount of rapidly boiling water in a covered utensil and the water brought again, quickly, to the boiling temperature.
2. The length of the cooking period should be just sufficient to bring about the desired degree of doneness.
3. The vegetable should be served as soon as it is done.

Acidity and stability of ascorbic acid. As has been said, the acidity of the cooking water has an important effect on the stability of both thiamine and ascorbic acid. This is

⁵ Brown, E. J., and Fenton, F., "Losses of vitamin C during cooking of parsnips," *Food Research*, Vol. 7 (1942), pp. 218-226.

Barnes, B., Tressler, D. K., and Fenton, F., "Effect of different cooking methods on the vitamin C content of quick-frozen broccoli," *Food Research*, Vol. 8 (1943), pp. 13-26.

Could, S., Tressler, D. K., and King, C. G., "Vitamin C content of vegetables. V. Cabbage," *Food Research*, Vol. 1 (1936), pp. 427-437.

Hollinger, M. E., and Colvin, D., "Ascorbic acid content of okra as affected by maturity, storage, and cooking," *Food Research*, Vol. 10 (1945), pp. 255-259.

evident in the case of tomatoes, which are relatively high in acid content and which, apparently, suffer little reduction in their original ascorbic acid and thiamine content upon cooking.

Raw vegetables and conservation of ascorbic acid. The effect of the protective action of acid upon destruction of ascorbic acid is also encountered in the preparation of vegetables to be used raw. Sliced tomatoes, for example, with their high acidity, undergo no perceptible loss in this vitamin when held in the refrigerator for as long as several hours. On the other hand, a less acid vegetable, such as cabbage, when cut for serving as in coleslaw, suffers an appreciable loss in this nutrient; even so, this loss need not be serious if this type of vegetable is cut with a sharp knife so that the tissues are subjected to as little maceration as possible, and if the cut vegetable is held in the refrigerator for only a moderate length of time before serving.

Vegetable cookery and retention of soluble nutrients. Nutrient losses just discussed that are due to high temperatures used and to oxidation during vegetable cookery are entirely in respect to vitamins. But losses, due to the leaching out of nutrients to become dispersed in the cooking water, include not only *water-soluble vitamins* but *soluble salts, sugars, and water-dispersible proteins*. These vitamins include ascorbic acid, thiamine, riboflavin, and niacin. The mineral salts include sodium and potassium salts, which are generously distributed in food materials, and soluble salts which contain the elements iron, calcium, and phosphorus, sufficient supplies of which to meet body needs are more difficult to obtain. Any dissolving-out of sugar in this manner is of importance chiefly because of accompanying loss in flavor in the cooked vegetable. Loss in proteins in this way is inconsiderable. But vitamin losses by solution, in addition to those effected by heat and oxidation, and the carrying-out of soluble salts can be nutritionally serious.

It is not surprising, therefore, that researches have been

carried on, and are still in progress, with the aim of establishing methods of vegetable cookery which will reduce the loss of these soluble nutrients to a minimum.⁶

Accordingly, *for conservation of soluble nutrients*, recommended cooking procedures are as follows:

1. When suitable, vegetables can be baked in their skins.
2. They can be steamed, whole and unpared.
3. They can be boiled, whole and unpared.
4. When necessary to cut a vegetable, it should usually be cut in large pieces in order to keep area of contact between the vegetable and water as small as is possible. (See remark C.)
5. When the vegetable is boiled, the least possible amount of water should be used, and the utensil should be covered.
6. The cooking period should not be prolonged beyond that necessary to bring the vegetable to the desired degree of doneness, and it should be served immediately.
7. The cooking liquid should be used whenever possible.

Remarks concerning foregoing recommendations.

A. It will be noted that items 5 and 6 in respect to conservation of soluble nutrients are in agreement with recommendations given for conservation of ascorbic acid (p. 246).

B. Cooking vegetables by *baking* and by *steaming* are among suggested measures for conservation of water-soluble nutrients. But these procedures are less favored for conservation of vitamins that are destroyed by heat and by oxidation, for the reason that the heat penetration of the vegetable is so slow that any favoring enzyme present is able to catalyze the destruction of considerable of this vitamin before it—the enzyme—is destroyed at the higher temperature eventually obtained.

C. In regard to the recommended practice of cutting vegetables into large pieces when boiling them, if they must be cut up at all, an

⁶ Although experimental investigations as regards cookery procedures for vegetables have been carried out more extensively in reference to losses of ascorbic acid and of iron salts than to losses of other water-soluble vitamins and other mineral salts, it is quite properly assumed that findings in regard to these nutrients are significant of losses of other water-soluble vitamins and mineral salts.

exception can be made. The vegetable can be cut into small pieces, if, by so doing, it becomes possible to use such small amounts of cooking water that the portion remaining can either be served with the vegetable or used in some other way—possibly blended with tomato or other vegetable juices as a vegetable cocktail. In this way all soluble nutrients are conserved, also conservation of ascorbic acid is aided, since heat penetrates small pieces of vegetables more quickly than large pieces, thereby destroying the enzyme which speeds the oxidation of this vitamin.

Summary—advised cookery procedures. The foregoing has been a somewhat detailed discussion of the “whys and wherefores” of the effects that cooking of vegetables in various ways has upon their appearance, palatability, and nutritive value. There may be conflicts: one cookery method may yield a product that is not aesthetically appealing but will preserve a major portion of the nutrients; another method of cookery may preserve the original attractive appearance of the vegetable, but will cause loss of a considerable portion of the nutrients.

Since conflicts may exist, a choice of method to be used frequently becomes an individual matter. But, in general, after taking into consideration appearance, palatability, and nutritional values of products concerned, advised practices for vegetable cookery are as follows:

1. Make frequent use of raw vegetables.
2. Bake vegetables frequently.
3. When boiling vegetables:
 - a.* In all cases put them into boiling water and bring the cooking water again to boiling temperature as quickly as possible.
 - b.* If they are large and with skins, such as beets, potatoes, and corn on the cob, use moderate amounts of water and a covered utensil.
 - c.* If the vegetable is strong-flavored, as is the case with onions and members of the mustard family, use relatively large amounts of boiling water, an uncovered utensil, a short

cooking time, and serve immediately. Or if the vegetable is of the mustard family and can, like cabbage, be cut into small pieces, a cooking procedure as in (*d*) may be used.

d. For all other vegetables, including peas, snapbeans, carrots, and spinach, use the smallest amount of boiling water that is possible, a tightly covered utensil, a short cooking time, and serve immediately with the cooking liquid—or save this to use in some other way.

e. Avoid the use of baking soda in the cooking water.

Regarding the use of baking soda in cooking vegetables. The addition of small amounts of baking soda to the water in which green vegetables or dried legumes are being cooked is a practice that is frequently encountered. Although the slight alkalinity that it gives to the cooking solution does intensify the green color of the chlorophyll pigment (p. 237) and aids in the softening of the skins of legumes, the use of baking soda is definitely not advised. The reasons are: Baking soda tends to destroy the natural flavor of the vegetable. The cooking time must be carefully controlled, since any overcooking of the vegetable in such an environment causes it to become excessively softened and mushy in texture. Both thiamine and ascorbic acid are more extensively destroyed as the cooking water becomes less acid (more alkaline). It must be admitted, however, that at the present time experimental evidence in this matter is slight and that which is available is somewhat contradictory.

Concerning the use of pressure saucepans. Pressure saucepans which are coming into quite general use today provide an effective way of using small amounts of cooking water and of securing quick heat-penetration of food. They also have an advantage over ordinary saucepans of lessening the contact of vegetable tissues with oxygen, since much of the air is exhausted from the saucepan at the beginning of the cooking period. Nevertheless, this type of equipment must be used with caution, since extension of the cooking period

beyond the desirable degree of doneness of the vegetable causes considerable increase in ascorbic acid destruction,⁷ no doubt because of the high temperature involved—approximately 250° F. Also, even a small degree of overcooking is liable to accentuate the undesirable flavor of the strong-flavored vegetables. This, however, is a matter of individual concern.

STORAGE OF VEGETABLES

Qualities affected. After vegetables are harvested, processes which brought about their ripening on the plant continue and, unless checked by proper storage conditions, the changes effected quickly cause deterioration in quality of the vegetables as reflected in a loss in crispness, flavor, and food value. It is a loss in sugar content that is largely responsible for deterioration in flavor, while loss in both sugar and vitamins causes loss in food value.

With respect to retention of food value, interest is centered chiefly on storage conditions that will conserve the ascorbic acid and carotene value of vegetables, inasmuch as these two vitamins are especially susceptible to destruction during post-harvest holding. Therefore, it is reasoned that if conditions are such as to conserve these two vitamins, it is probable that other components—including sugars and vitamins—will also be conserved.

Naturally, immediate use after harvesting is the best way to conserve high quality in vegetables in all respects; but, since immediate use is not usually possible, good storage conditions must be relied upon.

Storage in markets. If the household depends upon markets for its vegetable supply, only those markets should be patronized where there is a quick turnover of stock and where measures are observed for keeping vegetables fresh while holding them for sale. An ideal storage condition for

⁷ Barnes, B., Tressler, D. K., and Fenton, F., *op. cit.*, pp. 13-26.
Brown, E. J., and Fenton, F., *op. cit.*, pp. 218-226.

a short period is that of surrounding the vegetable with ice. Certainly they should be kept moist.

Home storage. For home storage, even if the length of time is short before usage, vegetables should be held at relatively low temperatures, either in a cool cellar or a refrigerator. This precaution is important, because at these low temperatures the vitamin content of vegetables is preserved—although to different extents for different vegetables—for as long as forty-eight hours of storage.

It has been discovered that loss of carotene in lettuce—and the same should no doubt hold true for similar vegetables—parallels loss in moisture from the leaves; hence the extent of wilting of lettuce may be taken as a standard of its value as to carotene. It follows that the hydrator of the modern refrigerator is an excellent place for the storage of such vegetables, since, in this closed storage space, the low temperature, high humidity, and absence of air currents check evaporation and the vegetables retain their original freshness for some time. Indeed, when kept in a hydrator, lettuce retains most of its original carotene content even up to seven days of storage.⁸ If necessary, hydrator conditions can be simulated by use of the special moisture-proof bags, such as are now available, or by means of tightly covered bowls, with both bags and covered bowls placed in the coldest part of the refrigerator.

Selection of vegetables. A discussion of the selection of both vegetables and fruits appears in the same section (p. 268) in Chapter XX, "Grading and Selection of Fruits and Vegetables."

SUPPLEMENTARY READINGS

BEATTIE, J. H., and ROSE, D. H., *Home Storage of Vegetables and Fruits*, United States Department of Agriculture, Farmers' Bulletin No. 1939 (1943).

⁸ Harris, R. L., and Mosher, L. M., "Effect of reduced evaporation on provitamin A content of lettuce in refrigerated storage," *Food Research*, Vol. 6 (1941), pp. 387-393.

- HALLIDAY, E. G., and NOBLE, I. T., *How's and Whys of Cooking*, 3rd ed. Chicago: The University of Chicago Press, 1946.
- JUSTIN, M. M., RUST, L. O., and VAIL, G. E., *Foods*, rev. ed. Boston: Houghton Mifflin Company, 1940.
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- , *Food Products*, 4th ed. New York: The Macmillan Company, 1948.

CHAPTER XIX

FRUITS

Fruit growing in the United States. As is the case with various other countries, fruit-growing has become an important industry in the United States, where large quantities of many kinds of fruit are produced. Although any fruit that thrives in a temperate climate can be grown in almost all parts of this country, it has become the practice in recent years to localize the production of some fruits, including apples, peaches, and grapes, in sections where soil and climatic conditions are most favorable for the growing of the particular kinds and varieties concerned. Fruits which require a sub-tropical climate, however, can be produced only where conditions prevail which favor their growth. It is for this reason that the citrus fruit-growing industry is located only in Florida, California, Arizona, Texas and other Gulf States. And there are fruits which grow only in a tropical climate and cannot, therefore, be cultivated in the United States; hence the entire supply of these fruits, chief among which are bananas and pineapples, must be imported.

What are fruits. Fruits are the seed-bearing parts of plants and thus, from a botanical view, they are related to cereal grains, legumes, and the fruit-vegetables such as tomatoes and squash. They do, however, have these distinguishing features: (1) during ripening, the structural part of the plant directly surrounding the seed becomes fleshy and succulent and, (2) when ripe, fruits are sufficiently rich in sugar as to taste sweet. Because of these important features,

fruits are easily differentiated, on the one hand, from cereal grains and legumes and, on the other hand, from the fruit-vegetables. It is also a fact that fruits have a higher acid content than have the fruit-vegetables.

Composition of fruits. The *water* content of fruits is high, ranging from approximately 80 to 90 per cent of their total weight for all kinds of fruits, except the banana and the fresh-prune, both of which contain only about 75 per cent *water*. *Carbohydrates* rank next in respect to quantity of foodstuffs present. *Cellulose* and *pectic substances* are components of the structural framework and intercellular materials of fruits; the *sugars*, sucrose, glucose, and fructose, are in solution in fruit juices. Although, from a palatability viewpoint, the sugar components are of considerable importance, actually they are not present in sufficiently large amounts to render fruits of any great consequence as energy foods. The *protein* and *fat* contents of fruits are negligible.

Mineral elements and vitamins. Fruits possess these foodstuffs in such quantities that they are outstanding among all natural foods as sources of these nutrients.

Mineral elements. Among the mineral elements provided by fruits are *calcium*, *phosphorus*, *manganese*, *copper*, and *iron*. They are present, mainly, as constituents either of *inorganic salts* or of salts of the several *organic acids* which are characteristic of fruits (p. 345).

Ascorbic acid. Ascorbic acid is chief among the vitamin components of fruits. In fact, fruits and vegetables are its most important food sources. The quantity of ascorbic acid varies among different kinds of fruits, with strawberries and citrus fruits containing the largest amounts. It is also true that the quantity of *ascorbic acid* varies among different varieties of the same kind of fruit.

Vitamin A. The vitamin A value of fruits is also of significance in that *carotene* (provitamin A) is among the *yellow carotinoid pigments* that are widely distributed among these natural food products. In this respect {apricots are so out-

standing as to be considered one of the most important plant sources of vitamin A; the banana also contains significant amounts of vitamin A value.

Fruit acids. The acid quality of fruits is due to the presence of organic acids. Fruits also contain salts in which organic acid radicals are in combination with various mineral elements; among these salts potassium acid salts frequently prevail, such as potassium acid citrate in citrus fruits and potassium acid tartrate in grapes, (p. 352). Although several different acids and their salts are present in every fruit, usually some one acid predominates in a specific kind of fruit. Thus, citric acid predominates in citrus fruits, such as grapefruit, oranges, and lemons; it also predominates in berries. Malic acid prevails in orchard fruits, which include apples, pears, and peaches. Grapes are unique for their content of tartaric acid and tartrate salts; while cranberries and prunes are peculiar for the presence of quinic and benzoic acids.

Metabolic effect. From an aesthetic viewpoint, the acid components of fruits are of value because of their contribution to flavor. From a dietary viewpoint their chief importance lies in the effect that their metabolic products have upon the natural alkalinity of blood and lymph. When taken in with the food they continue as acids during both salivary and gastric digestion; hence they increase the acidity of these digestive masses. But considerable proportions of the organic acids and organic salts that are components of such fruits as tomatoes and citrus fruits—chiefly citric acid and citrate salts—upon absorption from the intestinal tract become oxidized in the cells to potassium hydrogen carbonate, which is alkaline; hence, when this salt enters the lymph and blood it helps to maintain the natural alkalinity of these fluid media. But quinic and benzoic acids of such fruits as cranberries and prunes, after absorption, are converted into hippuric acid, which, being distinctly acidic, decreases the alkalinity of body fluids. Less is known of the metabolic fate of malic acid and the same is more or less true of tartaric acid and its salts.

Pigments. Much of the enjoyment in using fruits arises from the pleasing colors which they display. (The pigments

which impart these colors belong to the same four classes as do the pigments that have already been discussed as components of vegetables (p. 237). However, unlike vegetables, among fruits, especially in the stage of ripeness in which they are commonly used, chlorophyll is not important because this green pigment tends to disappear; but, at the same time the yellow, orange, and red of carotinoid pigments and the several colors of anthocyanin pigments become more apparent. Anthocyanin pigments are conspicuously dispersed among fruits, to which they impart a variety of their red, purple, and blue shades.

Tannins. Tannins are distributed rather widely in fruits but the amount present varies greatly among different kinds, also among different varieties of the same fruit. They are responsible for any bitter taste and astringent quality and, at least in part, for the discoloration of cut surfaces of fruits when exposed to air (p. 264). The presence of tannins is more noticeable in unripe than in ripe fruits, but the reason for this is not entirely clear. It may be that during the ripening process tannins are changed into insoluble compounds, or into compounds that are soluble but which have different tastes.

Changes in fruits during ripening. Life processes that go on throughout tissues of plants include the sequence of chemical changes that leads first to maturity and then to decay of their fruits. It is when this sequence of changes is allowed to progress to full maturity that fruit products of highest quality are obtained. Beyond this stage, unless the fruits are used or are subjected to conditions that will maintain them in their fully ripe condition, these changes will continue and lead to deterioration and final decay, in which condition the fruits can no longer be used as food.

The ripening process is accompanied by: (1) a softening of the cell walls and framework tissues, caused, in part, by a progressive conversion of protopectin to pectin (p. 332); (2) a decrease in chlorophyll and an increase in the carot-

inoid and anthocyanin pigments; (3) a decrease in acid content; (4) a decrease in starch accompanied by a marked increase in sugar. For example, it is reported¹ that in the change of starch to sugars in bananas, an increase in total sugars occurs of from 2 per cent in the green fruit to approximately 20 per cent in fruit which is fully ripe.

Harvesting of fruits. In most instances, if fruit is to be used for immediate consumption it should be picked when all of the above-mentioned effects have been carried to the point at which the fruit is fully ripe. But the marketing of large quantities of fruits is carried on through commercial channels, which usually necessitates their transportation for long distances; as a consequence, considerable delay may occur between harvesting of the fruits and their sale in retail stores. When this is the case, fruits are usually harvested before they are mature, with the preferred stage toward maturity being determined by the particular type of fruit concerned. For example, with bananas and pears, harvesting takes place while the fruit is still in a decidedly green stage, since it has been found that this practice leads eventually to products of finest flavor when they reach the retail markets.

✓ **Care of fruit in the home. For present use.** When fruit is brought into the home it should be sorted for degree of ripeness and for general quality, in order that any pieces that are fully ripe or that are injured in any way may be used first, and the less ripe and more perfect specimens set aside for future use. The fruit should then be placed, loosely, in containers and stored in a cool, fairly moist, environment. This is necessary inasmuch as the series of reactions that leads to the ripening of the fruit on the plant continues after it is harvested, and, unless the reactions are checked by cool temperatures, they are carried forward with resulting decay of the fruit.

¹ Poland, G. L., Manion, J. T., Brenner, M. W., and Harris, P. L., "Sugar changes in the banana during ripening," *Industrial and Engineering Chemistry*, Vol. 30 (1938), pp. 340-342.

Exception. An exception to the above "rule" for home storage of fruits that are to be used within a short period of time is in respect to bananas, which are usually purchased green or partially ripe. These require holding at room temperatures, or only slightly below, in order that the ripening process can continue until the yellow-colored skin with brown flecks appears which is characteristic of this fruit when it is ripe.

For a long storage period. When fruit is purchased in quantity for use throughout winter months, temperatures of only slightly above freezing are best for storage. With apples, which are harvested at the fully-ripe stage, the quality is best preserved if they are held at approximately 30 to 35° F. Furthermore, it has been found that when apples are stored at these temperatures they retain a large proportion of their original content of ascorbic acid. Fall or winter pears should also be held within this temperature range; however, unlike apples, pears are harvested while still green, therefore, before using, they should be removed from storage and held at room temperatures long enough to become ripe.

Importance of washing fruits. Whenever fruit is used, whether it is to be served raw or prepared and cooked by any of the several cooking processes, it is well to make it an established practice to wash the fruit thoroughly as an initial step. This is recommended as a sanitary measure for two reasons. *First*, fruits that are on the market are handled by a number of people in the process of picking and subsequent packing and marketing, and no sanitary measures toward personal cleanliness are required of these workmen. *Second*, fruits should undergo a thorough washing for the purpose of removing any dried residue from sprays that may persist on their skins. This latter possibility comes about because of the practice of spraying trees in order to prevent infestation of the fruit with insects, fungi, or other plant pests. And these sprays, if ingested, are frequently injurious to man. It is true that the public is protected to quite an extent by a *Federal law* which

requires that all previously sprayed fruits which are shipped under rulings that apply to interstate commerce must be washed in order to remove any clinging spray residue. It is true, too, that *some states* also have such regulatory laws which apply to fruits marketed within their respective borders. But, despite these protective laws, some dried spray may still cling to the fruit even after it is washed and marketed. Finally, it is probable that fruits raised and sold within borders of states which have no such protective laws may have considerable residue on their skins when they reach the consumer.

FRUIT COOKERY

In the home, when for immediate use, fresh fruits are customarily served in the raw state, although sometimes they are cooked, as in the instance of baked apples and apple-sauce. Toward meeting a variety of future uses, to some extent in the home but extensively on a commercial scale, fruits are used for making jellies, jams, and marmalades; and they are canned, frozen, and dried. Discussions of home processing of fruits for jelly-making, for canning, and for quick-freezing will be found in other chapters in this text. The chief interest in this chapter is in the preparation of fruits for immediate uses and in cooking methods for both fresh fruits and dried fruits.

Used raw. It is probable that for many people there is no more pleasing or satisfactory use of fruits than to serve them raw. In this condition a fruit may be eaten out-of-hand; or raw fruit can be prepared for serving with meals in various attractive ways. For example, with oranges and grapefruit cut in half, the flesh can be loosened from the dividing membranes in each half and then served in the skins. Or these fruits may be sectioned, in which case the skin with lining membrane is first cut away from the whole fruit, after which the sections are separated carefully from the dividing membranes between them before the fruit is served. Also, several kinds of raw fruits may be cut and mixed to make a

fruit cup or fruit cocktail, as the latter is frequently called. Finally, salads made of several kinds of raw fruits are always refreshing.

Incidentally, the use of raw fruit as a between-meal or an after-school lunch for children is an excellent dietary practice that should be encouraged.

Cooking methods. The simplest methods that are used for cooking fruits are *baking*, and *boiling in water* for the purpose of obtaining various fruit sauces. *Sautéing* and *broiling* of fruits are often preferred cooking methods when fruits are served as an accompaniment to meat in the main course of a meal. Besides these methods for cooking fruits there are many others that are more elaborate, directions for which can be found in various cookbooks.

Changes effected in cooking fruits. The changes which take place in all plant tissues, including those of fruits, which cause their tissues to become more tender during cooking, have been discussed previously in connection with the cooking of vegetables (p. 239). Hence, the discussion at this time will be concerned with items that pertain specifically to *fruit cookery*.

Cooking of fresh fruits. In vegetable cookery it is the usual aim to stop the cooking process when the vegetable tissue becomes just soft, without suggestion of disintegration. But in cooking fruits, depending upon the character of the product desired, the process is continued: (1) sometimes to the state of complete disintegration; (2) sometimes until the fruit is completely softened but without losing its shape.

If a completely disintegrated fruit is desired, such as apple-sauce or a sauce of pears or cranberries, the fruit is covered with boiling water and the boiling is continued until disintegration occurs, at which time the mass should be stirred until the consistency of one's choice is obtained; if a completely pulpy consistency is desired, the sauce can be forced through a strainer.

When it is preferred to keep the cooked fruit in whole

pieces, extensive tissue softening should not be permitted. Toward this end, the fruit is placed in a dilute sugar sirup, instead of just water, and allowed to boil gently for only long enough to make the fruit tender and to concentrate the sugar sirup sufficiently. The reason for this procedure is that sugar sirup exerts a slight strengthening action upon the cell walls of fruit tissue, which prevents their disintegration to some extent. However, since this effect becomes more pronounced with sirups of increasing sugar concentration, it is well to start the cooking with a fairly thin sirup, in order to obtain some softening of the tissues, and then to allow the solution to become progressively more concentrated as the water evaporates from it.

Some fruits, such as different varieties of apples, upon cooking, behave differently with regard to the ease with which their tissues become softened. This is particularly noticeable in using apples for making a pie. With some apples, sections contained within the pie cook to a fluffy mass, with others the sections are inclined to remain in the same shape in which they were cut. For this particular use it is probably wise to select such apples as will effect a compromise condition between these two extremes—that is, apples whose cut pieces will become sufficiently soft so that they retain some identity of shape but at the same time will attain a fluffy character. Experience in the selection of the particular varieties of apples to use for each cooked product intended is an undoubted advantage. Some varieties of apples, their chief market seasons, and their uses are given in the accompanying table.

Cooking of dried fruits. A fruit from which a large portion of the original water content has been evaporated, and the solids thus greatly concentrated, is known as a dried fruit. Dried prunes, apples, peaches, and apricots are representative of this type of product. The shriveled appearance that is characteristic of dried fruit should be corrected by soaking it for a short time in cold water before the fruit is cooked.

APPLE VARIETIES

Variety	Chief market season	Uses to which well suited ²				
		Dessert	Baking	Pie	Sauce	Jelly
Astrachan	July-August	x		x	x	x
Baldwin	November-April	x	x	x	x	
Ben Davis	November-April		x	x	x	
Cortland	September-December	x	x	x	x	x
Dutchess	July-August		x	x	x	x
Fameuse	October-December		x			x
Gravenstein	July-September	x		x	x	
Grimes						
Golden	October-January	x		x	x	
Jonathan	October-February	x	x	x	x	x
Maiden Blush	August-November			x	x	x
McIntosh	October-January	x	x	x	x	x
Northern Spy	October-March	x	x	x	x	x
Rhode Island						
Greening	October-March			x	x	
Rome Beauty	November-May		x	x	x	x
Stayman						
Winesap	November-April	x	x	x	x	
Transparent	July-August			x	x	
Wealthy	September-December		x	x	x	x

² These data in regard to uses to which various varieties of apples are well suited are obtained from the sources listed below. They represent a summary of findings among which, as would be expected, there is not complete agreement.

- Child, A. M., and Brand, R. H., *Using Minnesota Apples*, Agricultural Extension Division, University of Minnesota, Special Bulletin No. 185 (1937).
- Hill, R. G., *A Fruit and Vegetable Buying Guide for Consumers*, United States Department of Agriculture, Miscellaneous Publication No. 167 (1941).
- Milam, A. B., and Gardner, H. B., *Comparative Cooking Qualities of Some Common Varieties of Apples Grown in Oregon*, Oregon Agricultural Experiment Station, Bulletin No. 124 (1915).
- Minton, E. S., Garvin, A. L., and Beach, F. H., *Eighty-five Ways of Using Apples*, Agricultural Extension Service, The Ohio State University, Bulletin No. 202 (1940).
- Pfund, M. C., *The Culinary Quality of Apples as Determined by the Use of New York State Varieties*, Agricultural Experiment Station, Cornell University, Memoir No. 225 (1939).
- Stokdyk, E. A., Erdman, H. E., West, C. H., and Allen, F. W., *Marketing California Apples*, Agricultural Experiment Station, University of California, Bulletin No. 501 (1930).

Explanation: During the soaking of a dried fruit, osmotic pressure forces (p. 9) are at work with the skin and walls of the myriads of cells of the fruit acting as permeable membranes. Thus, when such a fruit is put into water, since the solids within the cells are highly concentrated, the solution within them will have a higher osmotic pressure than that of the surrounding water; as a result, more water will diffuse into than out from the fruit, thereby causing it to become more and more plump. At the same time, some of the dissolved solids within the cells—sugars, mineral salts, and acids—will diffuse outward through the walls to dissolve in the surrounding water (Fig. 3). This two-way diffusion of water and soluble salts and sugars will continue, with accompanying swelling of the fruit, until equilibrium is set up between the concentration of solutes within the cells and the surrounding solution; or until the membranes burst; or until cooking is started, in which case the permeable membranes become destroyed by heat.

Discoloration of cut fruit. When certain fruits are pared or cut in any way that will expose their inner tissues to air, a brown color appears which becomes darker as the fruit is allowed to stand. This phenomenon is most troublesome with apples, pears, peaches, plums, and bananas. Although the cause of the darkening is not explained with complete satisfaction at the present time, it is known that tannins, flavone pigments, and other components of the fruit cells are involved. Evidence is provided by the fact that both tannins and flavones give brown-colored pigments when oxidized. Hence, it is reasonable to assume that, when fruit tissues are cut and components become exposed to oxygen of the air, oxidizing enzymes present within fruit cells catalyze the reactions, as to tannins and flavones, that are responsible for these effects. It is also a fact that tannins and flavone pigments react with iron salts that result from contact of the acids of fruits with ordinary steel-bladed knives to give greenish-purple compounds.

Because these color changes detract from the appearance of fruit, with resulting decrease in its aesthetic appeal, meas-

ures should be taken to prevent their occurrence. The knife used for cutting fruit should be carefully selected, in order to avoid the formation of iron salts; preferably it should be a silver fruit knife, or one made of stainless steel or of plastic material. As the fruit is cut it may be dropped either into a salt solution or a solution of both salt and acid (p. 318), or it may be put into a sugar sirup. If any one of these procedures is not feasible, the cut fruit may be covered sparingly with grapefruit juice, lemon, or pineapple juice, or even a solution of cream of tartar. Which of these means is preferred will depend sometimes upon materials that are available and sometimes upon the use for which the fruit is intended; obviously, materials should not be used that will mask the original flavor of the fruit. As a further safeguard against darkening, the fruit, covered with the solution, can be placed in the refrigerator where cold temperatures delay the reactions that are responsible for making the dark-colored compounds.

When cut fruit is to be cooked, as in making pies, sauces, or other cooked dishes, a slight darkening is not objectionable since it does not seem to be noticeable in the cooked product. Even so, it is a good practice to cut fruit just before using it for such purposes.

Effect of cooking on food value of fruit. The nutritive value of cooked fruits is high. Since they retain their relatively high acidity during cooking, the destruction of carotene and ascorbic acid is negligible (p. 246); and these vitamins are the most sensitive of all to destruction. Also, because juices arising from cooked fruits are customarily served with them, there is little loss of soluble nutrients such as sugars, mineral salts, and water-soluble vitamins.

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CHAPTER XX

GRADING AND SELECTION OF FRUITS AND VEGETABLES

Not so long ago, when one went to market to purchase the family supply of fresh fruits and vegetables, the products obtainable were limited to those grown locally. But today the situation is different; in most markets, regardless of location, one is quite likely to find a considerable display of vegetables and fruits, brought from near and far, from which to make a selection. Obvious factors that are responsible for the general availability of these desirable foods are as follows:

1. *Storage facilities*, especially as they apply to cold storage, have been so perfected that it is possible to carry over many agricultural products in prime condition from months of high production for use during periods of low or no production.

2. *Rapid transit in cold storage* in refrigerated freight cars and in refrigerated units in ships and airplanes makes it possible now to carry fresh fruits and vegetables for long distances, from production areas to consumers, either within the limits of the country itself or even from one country to another.

Quality-grading of fruits and vegetables. The practice of quality-grading of fruits and vegetables was started in 1907 when Congress authorized the Secretary of Agriculture to formulate standards for farm produce. The program has steadily expanded until, at the present time, grade standards

have been described for almost all fruits and vegetables. They include specifications in regard to the particular variety of fruit or vegetable involved, its color, size, shape, degree of maturity, and freedom from such defects as may be caused by dirt, disease, insects, freezing, or mechanical injury.

A service to growers and shippers. As part of this program of quality-grading, the Department of Agriculture provides an inspection and grading service to growers and shippers of farm produce, for the purpose of certifying its quality and condition when offered for sale in interstate commerce, or from central markets such as are located in large cities. The service is designed mainly to promote efficient marketing practices, since fruits and vegetables pass through many dealers' hands on their way from producer to retailer, and each dealer en route, frequently located at a distance from the preceding one, is thus assured of securing a product of known quality. With some exceptions ¹ this grading service is optional.

The consumer benefits by the quality-grading of these foods, although, in some instances, indirectly. For more perishable goods in the retail market, the consumer will not always find the quality-grade designation carried on the container in which the goods are displayed. This is owing to the fact that such fruits and vegetables, having undergone some unavoidable deterioration during transportation, upon reaching the retail market have fallen somewhat below the grade designation assigned to them in production areas where they were graded, packed, and labeled.

For less perishable products in the retail market, such as potatoes and onions, the buyer will often find the quality-grade designation still stamped upon the bags or other containers in which the products were originally packed.

An intelligent selection of fruits and vegetables. There are various factors which one should take into con-

¹ Herrick, A. D., *Food Regulation and Compliance*, Vol. I, Chapter 13. New York: Revere Publishing Company, 1944.

sideration when purchasing fruits and vegetables. These are discussed in the following sections.

Use. A first consideration is in respect to whether the fruit or vegetable is to be served raw or cooked. If it is to be served raw, and the product is after the order of pears or tomatoes, it is aesthetically pleasing to have perfect specimens of even size. But if the product is to be cooked, a selection of specimens somewhat uneven in size can be made and some surface blemishes are permissible, provided they do not affect the interior portions of the product. †

The particular variety of fruit or vegetable is also frequently a factor to be considered in connection with the intended use. For example, yellow onions may be preferred for some uses and white onions for others; also, in a selection of apples, some varieties are best suited for baking while others are suited to general cookery uses (p. 263).

Waste. In purchasing a fruit or vegetable, the buyer should give thought to the amount of waste that will be involved. Obviously a certain amount of unavoidable waste is inherent with many fruits and vegetables, such as pods of Lima beans and peas, husks of corn, outside coarse stalks and leaves of cauliflower, and thick skins of oranges. Recently, however, it has come to be regarded as good practice in menu-planning to make use of parts of certain vegetables that were formerly discarded. Accordingly, in many homes, these days, the inner stalks and leaves of cauliflower, the leaves of broccoli, beet tops, and even carrot tops are cooked and served; how extensively they are used is of course a matter of individual preference.

Although vegetables and fruits that are damaged or wilted are frequently offered for sale at a lower price than those of good quality, the resulting waste, accompanied by possible decrease in nutritive value, usually renders these damaged products more costly in the end.

Unit of purchase. Still another purchasing consideration has to do with whether the fruit or vegetable is sold by

numbers, as one or two heads of cauliflower or a dozen oranges; or *by volume*, as in the instance of potatoes when sold by the peck; or *by weight*. Actually, purchase by weight has been found to be, generally, the most satisfactory from an economical viewpoint since, on the whole, this method provides greatest assurance of obtaining "value-received." But there are some exceptions; purchase of berries by volume measure is an example.

Quality of product. It has been said that the quality-grading of fruits and vegetables at the point of shipping has had a favorable effect upon the over-all quality of these commodities that are offered for sale in retail markets. Even so, an intelligent selection of fruits and vegetables for use in the home is all to the good. This necessitates a knowledge of characteristics which denote good quality in the various products. Although a complete description of these characteristics for all types of vegetables and fruits is beyond the scope of this text, a brief summary can be included. For greater details the student is referred to texts on the marketing of food products and to government² and state publications which deal with this subject. Such details as are included here for directing the selection of fruits and vegetables for family use are as follows:

Fruits, such as apples, pears, peaches, and plums, should have full color, a reasonable degree of firmness, and an absence of surface defects such as scale and bruises. *Berries* of all sorts and grapes should have full color, should be firm, and should have a plump, fresh appearance. They should be dry, clean, and free from foreign material, including sand and leaves. *Citrus fruits* should be well-colored and heavy for their size. They should have a fine-textured, bright skin; russeting of the skin, if not extensive, need not adversely affect interior quality. Grapefruit should be flat rather than

² Excellent material on this subject will be found in Hill, R. G., *A Fruit and Vegetable Buying Guide for Consumers*, United States Department of Agriculture, Miscellaneous Publication No. 167, 1941.

pointed at the stem end. Oranges of the tangerine type should have the rough and loose skins which are characteristic of this variety of fruit.

Salad plants and greens, which include spinach and kale, should be of good color, fresh, crisp, and tender. They should be free from wilted or yellowed leaves. Headed types of salad plants, like some varieties of lettuce, should be fairly firm. *Carrots* and other *root vegetables* should be firm, of good shape, and clean and fresh looking. The pods of *Lima beans*, *peas*, and all vegetables of similar type should be of a good green color, and well filled with seeds. They should be clean and bright in appearance and crisp and firm in texture. *Snapbeans* should be of a good green or yellow color according to variety. The pods should be clean and fresh in appearance, and firm, tender, and crisp in texture; the enclosed beans should be small. *Cauliflower* should be either white or creamy-white in color. The head should be firm and compact; not open and loose, a condition which is indicative of growth of the flower clusters. *Broccoli* should be of a good, dark green color. The clusters of buds should be compact and should not show any of the purple or yellow color of the flower. The stems should be tender, firm, and crisp.

Potatoes should be smooth, shallow-eyed, and free from any green coloration. Color of skin, and size and shape of this vegetable vary with the variety. Since this is one of the few vegetables in the retail market that is frequently found in the original container which carries the quality-grade designation, the inexperienced buyer is advised to depend upon this grading, when it does appear, rather than upon personal judgment for selection of potatoes for home use.

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CHAPTER XXI

BEVERAGES

COFFEE

The coffee plant is believed to be indigenous to Abyssinia. During the fifteenth and sixteenth centuries, Arabia was the greatest coffee-producing country in the world; from thence its cultivation spread throughout tropical countries in the old world and, in the early years of the eighteenth century, to the tropics of the western hemisphere, with the result that, today, Brazil takes the lead in world production of coffee. The United States ranks foremost in the amount of coffee consumed, approximately 96 per cent of the coffee imported into this country coming from Brazil and other Latin-American countries.

The coffee bean. (The coffee plant is a tall evergreen shrub which grows in the hot, moist climate that prevails in the tropical zone. It bears a small fruit which, when ripe, is dark red or crimson and so closely resembles a cherry that it is often called a "coffee cherry." Within the "cherry" are two seeds—the *coffee beans*; they are greenish-gray in color and oval in shape but with one side of each flattened so that the two beans lie close together. The beans are covered by a thin membrane known as the silver skin and, together, they are separated from the outer, fleshy part of the fruit by a parchment-like covering.) Occasionally a "cherry" contains only one oval seed, which is called a peaberry.

Before coffee beans are ready for marketing, all of the covering layers must be removed—silver skin, parchment,

fleshy, outer material, and skin of the fruit. There are two methods for effecting this separation, depending upon the particular location where the coffee is grown.¹ But the beans as they emerge from both procedures are called *green coffee* which needs only roasting and grinding before being used in making the coffee beverage.

Components of the coffee bean. Like other seeds, the coffee bean contains some starch, sugar, protein, and fat, with structural parts made up largely of cellulose. But of special interest from the viewpoint of its unique use in making coffee beverage are the components *caffeine*, *fat-like substances*, and *tannins*.

Caffeine is soluble in hot water and, when extracted during the brewing of coffee, gives the beverage its stimulating effect. It is present in the coffee bean in small amounts (approximately 1 to 1.5 per cent). *Fat-like substances* are largely responsible for the pleasing taste and aroma of the beverage. *Tannins* are undesirable components; if they are extensively extracted in the brewing, their presence gives the beverage an unpleasant bitter taste.

Preparation for market. Raw or green coffee has very little taste and aroma, hence the need for subjecting the beans to a roasting process in order to develop these desirable qualities before the coffee is ready for use in making the beverage.

Coffee blends. Since different varieties of coffee develop different flavors upon roasting, it is the usual practice of coffee dealers to mix several varieties into a "blend," prior to roasting, with the number and proportions of the varieties depending upon the particular coffee blend desired at the time.

Roasting. Roasting involves heating *green coffee* in large containers, designed so that the beans are kept in constant agitation, to temperatures ranging from approximately 390 to 480° F. The exact temperature used for roasting and the

¹ For details of these methods of obtaining green coffee beans the student is referred to books on food technology listed at the end of this chapter.

length of the roasting period vary according to the darkness of "roast" desired, whether *light*, *medium*, *dark*, or *very dark*. Usually different countries and even different localities in any one country have special preferences in this respect: Italian and French "roasts," for example, are dark or very dark.

Changes during roasting. Accompanying the loss of water during roasting certain complex chemical changes occur in various components of the coffee bean. A *partial carbonization of cellulose and other carbohydrates* takes place. These changes are responsible for the darker colors and brittle texture obtained in the roasted bean, and they doubtless have some influence, later, on the flavor of the beverage. But, more importantly, *changes in other organic compounds* occur with the production of substances which, being aromatic, volatile, and dispersable in water, are responsible for decided effects on coffee flavor. Among these are the aromatic substances often called by the inclusive name, *caffeol*. For a time at least, these substances, along with carbon dioxide gas which is also a product of roasting, are held captive in numerous, tiny cells within the bean. Roasting has little effect upon caffeine. Tannins, fortunately, are rendered somewhat less soluble than in the raw bean.

Changes after roasting. The captured carbon dioxide, together with other imprisoned gases, exert considerable pressure upon cell walls; consequently, since the walls are permeable, there is a tendency for the gases, accompanied by volatile, flavorful substances, to escape from the bean. Obviously, as this occurs, there is an accompanying loss in initial coffee flavor. An associated effect, which becomes apparent when coffee is held for longer than 9 or 10 days,² is the appearance of a stale flavor, which is believed to be due to the accumulation of substances made as the result of oxidation of certain components of coffee upon their exposure to air.

² Punnett, P. W., "The coffee problem," *The Journal of the American Dietetic Association*, Vol. 6 (1930), pp. 54-58.

These two types of changes that take place in the whole bean become accelerated to some extent when the roasted beans are ground, with the result that ground coffee when exposed to air soon becomes undesirable for use.

Vacuum packaging. In order to prevent loss of desirable substances and access of oxygen, thereby prolonging the time during which the initial high quality in ground coffee may be maintained, manufacturers have introduced the practice of packaging such coffee in evacuated, sealed containers. In this procedure coffee is packed into the containers which are then carried through a vacuum-sealing machine. This processing exhausts a large portion of the air held in the containers, then seals them tightly.

Carbon dioxide and gases from volatile, flavorable substances do escape for a time from ground coffee into the vacuum obtained within such a sealed package; but as these gases collect within the confined space, they set up an opposing pressure which prevents their further escape, thereby checking continued loss in desired flavor, as long as the coffee remains sealed. As for the stale-flavored substances, made through oxidation, so little air remains in the sealed container that any changes, due to reaction of components of coffee with oxygen, are practically eliminated.

It must be emphasized that when once a vacuum-sealed container is opened, conditions are such that all undesired changes pertaining to the coffee are again in operation. Hence this coffee should be used within a period of about 10 days. By storing the opened container in a refrigerator the extent of undesired changes can be reduced.

Coffee brewing. Brewing coffee involves holding the ground coffee in contact with hot water for a short period of time. The process is complicated, however, by the necessity for providing conditions during the brewing period which (1) will carry a maximum of caffeine and flavor components into the brew, but, at the same time, (2) will check *both* an escape of desired, flavorful substances into the air with the

steam, and a diffusion into the water of undesired tannins and other bitter-tasting materials.

Temperature and time. To obtain favorable brewing conditions, temperature of the water and length of the period of contact between the hot water and ground coffee are important factors.

Temperature. There is general agreement among coffee experts that the best temperature of water for extraction of caffeine from ground coffee is just below boiling, at about 200° F. They agree, too, that at or near this temperature, desired, flavorful substances also become extracted into the hot water, little being carried away with steam due to the fact that water is below its boiling point. Finally, it is found that at this temperature minimum amounts of bitter-tasting materials such as tannins are extracted, the reason being that these materials are less soluble at below-boiling than at boiling temperatures.

Time. A short period of contact of coffee with hot water is advised, since this provides for adequate extraction of both caffeine and flavorful components and gives little opportunity for loss of the latter; also during a short brewing period, there is less extraction of substances with a bitter taste.

Proportions of coffee to water. Since the strength of coffee beverage that is considered most desirable is a recognized personal factor, it is obviously impossible to stipulate a proportion of coffee to water for brewing that would be completely satisfactory to everyone in any group of people. But it is probable that 2 tablespoonfuls of ground coffee to 1 cupful (8-ounce standard measuring cup) of water represents a proportion that will give a beverage of medium strength which is quite generally acceptable.³

But as everyone who is responsible for purchasing coffee for family use knows, the fineness of the various grinds that

³ The Pan-American Coffee Bureau, in its literature, recommends larger proportions of coffee to water, namely 2 tablespoonfuls of coffee to $\frac{3}{4}$ cupful of water.

are on the market today ("drip grind," "regular grind," and so forth) influences the advised proportion of coffee to water, since the more finely the coffee is ground the greater will be the extraction of various components at a given temperature in a given time. But whatever the grind may be, it is extremely important that sufficient coffee be used so that brewing time need not be unduly prolonged.

Methods of making coffee and coffee-making equipment. There are two basic methods of preparing the coffee beverage, namely: the *steeping method* and the *drip method*. In the steeping method hot water is held in contact with ground coffee for several minutes. In the drip method the hot water is allowed to pass through the ground coffee either once or several times.

Although many coffee-making devices are available, it is a fact that, irrespective of its design, each one accomplishes the process according to one or the other of these two basic methods. The time-honored *coffeepot* in which "boiled" coffee is made provides a means of extraction by the *steeping* method. In the *vacuum-filter* coffee-maker, which is more modern and certainly more elaborate in design than the coffeepot, the beverage is also brewed by *steeping*; special features of this type of coffee-making device lie in the provision for more accurate control of brewing temperature than with the coffeepot and in the automatic filtering of the beverage.

Brewing coffee by the *drip method* can be accomplished either in a *drip coffee-maker* or in a *percolator*. Although these two devices are decidedly unlike in design, the essential difference as to brewing lies only in the number of times the hot water drips through the coffee—once in the drip coffee-maker as compared to several times in the percolator. In both of these devices the beverage is automatically filtered from the grounds.

Material used for coffee-makers. Excellent coffee can be brewed in any of these coffee-makers, selection of the type for use being entirely a question of individual preference.

But the material of which the device is constructed is important. Some metals may have a deleterious effect upon flavor of the beverage, especially if the coffee dispersion is held in contact with the metal for any length of time. For this reason one would do well to give preference to glass, porcelain, stone-ware, or enamel coffee-makers, or to those made of high-quality aluminum or of stainless steel, all of which materials have been found to be satisfactory. Coffee-makers that are plated with silver, nickel, or tin are less desirable since often, with continued use, the plating wears thin and the base metal, usually copper or iron, becomes exposed—and contact with the latter metals imparts undesirable flavor qualities to the beverage.

Care of coffee-makers. With the daily use of coffee-making equipment a sediment tends to collect on inner surfaces and, unless care is observed in washing the device, this sediment eventually causes the formation of a gummy residue. Since such a residue has a deleterious effect upon the flavor of the beverage, cleansing methods must be such as to prevent its formation.

Immediately after each use the coffee-maker should be washed in *hot, soapy* water; valves and tubes of percolators and all narrow **spouts** and crevices should be cleaned with a slender brush; then all parts should be rinsed in *hot, running* water; finally, all parts should be dried and the pot set aside with the cover only partly in place in order to allow for free circulation of air.

Such measures constitute daily care. Occasionally, possibly once or twice a month depending upon frequency of its use, a more thorough cleansing of the coffee-maker is advisable. If it is constructed of one of the nonmetallic materials or of stainless steel, it should be scoured with a good scouring powder. If it is made of aluminum, fine steel wool can be used with a mild scouring powder—one free from alkali, since alkali tends to darken this metal. If it is a tin- or silver-plated coffee-maker the use of steel wool should be avoided

because of the danger of exposing the iron or steel base, which, unless care is taken to thoroughly dry all surfaces, will tend to rust.

It is only by observing care to insure a scrupulously clean condition in the equipment in which coffee is made that a desirable, delicate flavor-quality in the beverage is made possible.

Grinds of coffee for specific types of coffee-makers. Coffee can be bought in the bean and ground either at the store or at home. In general two grinds are obtainable, choice of which is influenced by the coffee-maker in which the beverage is to be brewed, the finer of the two grinds being best suited for use in the vacuum-filter and drip coffee-makers, while the coarser grind is better adapted for use in the coffee-pot and the percolator.

Quality of coffee beverage. It has been said that strength of coffee is a matter of individual preference; therefore, no one standard of excellence in this respect becomes possible. But no matter what the strength, the beverage should be *clear* and *sparkling*, and should have a *delicious aroma* and *taste*.

These qualities of brew are obtainable upon following the recommendations for making coffee that have been discussed previously and are summarized briefly as follows:

1. The selection of a good blend of coffee is of first importance.
2. The coffee should be properly stored.
3. It should be used within a short period of time—probably not to exceed 10 days.
4. Careful attention should be given to:
 - a. the proportion of coffee to water (p. 276),
 - b. the “grind” of coffee in relation to the type of coffee-making device used,
 - c. the temperature of water during the brewing process (p. 276),

d. The length of brewing period.

5. The coffee infusion should be removed from the grounds as soon as brewed.

6. The beverage should be served immediately.

Concentrated coffees. *Liquid coffee* is a highly concentrated form of the beverage. It is manufactured by heating a coffee infusion under a partial vacuum, until sufficient water is evaporated to give a dispersion which contains the desired high concentration of coffee solids. Volatile, flavorful substances which escape during the evaporation of water are recovered and reintroduced into the concentrated product. *Instant coffee* is a powder. It is prepared by evaporating a coffee infusion to dryness under conditions that will minimize loss of flavorful components. In many instances sugar is added to the infusion before it is subjected to evaporation.

Both types of concentrated coffee are convenient for use in preparing the beverage on occasions when time is limited. Directions to be followed are always found on the labels of the containers.

TEA

Origin and present-day production. Tea is a plant that is believed to be native to both China and India; but the earliest records in regard to tea cultivation and the use of tea as a beverage come from China, where this brew was first used as a medicine. From China, the growing of tea plants as an industry spread to other Asiatic countries with the result that, at the present time, although China produces about one-half of the tea grown in the world, India, Ceylon, Java, and Sumatra far outstrip her in quantities of tea exported into world trade. Great Britain ranks first and the United States second as the two largest tea-importing nations.

✓ **Cultivation.** The tea plant is an evergreen bush which requires a moderately warm climate and plenty of rainfall for

growth; at maturity it reaches a height of from 3 to 4 feet. The plant thrives in lands ranging from sea level to over 7000 feet in elevation—in fact some of the finest-quality teas are obtained from plants that are grown at the highest of these altitudes. Tea cultivation requires extensive pruning so that the bush will send out a luxuriant growth of new shoots several times a year. The partly unfurled leaf at the end of the shoot, together with two or more other leaves, are the ones that are plucked for curing toward their ultimate use in brewing.

Classes of tea. Teas are classed either as green, black, or oolong, according to whether or not the leaves, after plucking and during manufacture into the finished product, are subjected to a fermentation process. *Green tea* is not fermented; *black tea* is fully fermented; *oolong tea* takes an intermediate place in that it is partially fermented. A brief description of the main features of the manufacture of each of these classes of teas follows.

Green tea. For this tea the leaves are first heated, in order to destroy enzymes and to evaporate enough water so that the leaves become flaccid and ready for rolling, which is the second step in the manufacture. Finally, the rolled and twisted leaves are heated until most of the remaining water is evaporated and they become dry and somewhat brittle.

Black tea. In making black tea, immediately after withering by means of mild heat, the leaves are rolled, then spread out and allowed to “ferment” for several hours. Actually, changes which occur in the leaves during this step in their processing are not those of true fermentation, instead they are changes which involve oxidation of certain components. The reactions concerned are catalyzed by plant enzymes. These enzymes remain enclosed in the cells of the leaves during withering, but are released and brought into intimate contact with leaf juices when the cells are damaged during the rolling process. When fermentation has progressed to the extent de-

sired, in order to destroy the enzymes and to continue evaporation of water, the leaves are heated until they acquire the final, characteristic, dry texture.

Oolong tea. The processes employed in making oolong tea are similar to those used in the manufacture of black tea, except that fermentation of the leaves is not carried as far, with the result that the finished tea is intermediate in character between green and black teas.

It is interesting to find that the different tea-producing countries, in the main, employ only one of the three methods of manufacture. Thus, black teas of commerce come from India, Ceylon, China, Java, and Sumatra; green teas from Japan and to a lesser extent from China, Ceylon, and India; while oolong teas come almost exclusively from Formosa.

Changes in tea during manufacture. Changes which take place in components of tea leaves, during processing, that are of importance in relation to the later use of the leaves in making the beverage, involve chiefly *pigments, tannins*, and certain *components that contribute flavor*. *Caffein*, which is present in the tea leaf to the extent of approximately 2.5 to 5.0 per cent, is apparently unaffected during any of the three processing methods employed.

During fermentation in the making of **black tea** some changes are effected as follows: Chlorophyll pigments are destroyed. Of tannins originally present, some are rendered insoluble, others are made into soluble compounds which impart the attractive, red-brown color to the beverage when the processed tea leaves are brewed. Flavor-giving components are made, some of which are volatile and account for the pleasant aroma characteristic of the beverage.

Since tea leaves are not subjected to fermentation in the making of **green teas**, the processed leaves retain some chlorophyll, the tannins remain more nearly in their original form, and there is less extensive development of flavorful components. As a result, the beverage made from green tea is

pale, yellowish-green in color and the flavor is more delicate than that of a black tea infusion.

Since the processing of leaves for the making of *oolong tea* is intermediate between that employed for black and green teas, the changes effected in the leaves are correspondingly intermediate in extent. As a consequence, oolong tea gives an infusion that ranges in character between those obtained from black and green teas—the color more nearly resembling the reddish-brown color of the infusion of black tea, the flavor being more nearly like that of green tea.

Whether the brew made from green, black, or oolong tea is the preferred one is entirely a matter of personal choice. But irrespective of class of tea, an excellent brew is possible only from an excellent grade of processed leaves.

Grades of tea. Factors affecting. The finest-quality teas are from the partly unfurled leaf at the end of the shoot and the two next below, these leaves being young and succulent. Poorer-grade teas are from still lower leaves. But the comparative excellence among either first-choice or second-choice leaves is influenced by several conditions which include: the climate, altitude, and soil conditions where the plants are grown; the manner of cultivation, and season of the year when the leaves are plucked. Another factor that affects quality of tea has to do with technics employed in processing the leaves. Finally, the quality of tea as it reaches the market further depends upon whether, for the packaging, leaves have been selected according to size or have been blended by mixing various sizes.

Names and grades. Teas are usually named according to the country where they are grown and processed, as India tea, China tea, and so forth. Further than this designation, names that indicate various grades of tea apply, as a rule, to *size and age of leaf*.

Black teas, no matter where grown, when made from the youngest leaves are designated as: *flowery pekoe* or *flowery*

orange pekoe, *broken orange pekoe*, and *orange pekoe*. And since younger leaves are considered to give finest quality of tea, it is probable that brands which carry these names can be regarded as best grades of black teas. Black teas, made from older and larger leaves, are called *pekoe* and *souchong teas*.

For *green teas* there is less uniformity among countries in the names by which leaves of various sizes and ages are designated. For example: China manufactures *gunpowder tea* from young leaves and *imperial tea* from older leaves, both of which teas have leaves rolled into ball-like shapes; then there are green teas from this country which carry the names of *young hyson* and *hyson*—these are younger and older leaves, respectively, that are twisted into a long shape rather than into balls.⁴

Brewing tea. In brewing the tea beverage an infusion is made of tea leaves in hot water. For best results careful attention should be given to certain details which may be regarded as rules for tea brewing. These follow:

1. The proportion of tea should be 1 teaspoonful or less (according to preference) to 1 cupful (8 ounces) of water.

2. The teapot—for which earthenware or other non-metallic material is preferred—should be warm.

3. Freshly boiling water should be poured over the tea leaves immediately upon its removal from the heat, so that upon contact with the leaves the water is almost at boiling temperature.

4. The pot should be covered and placed where it will keep hot and should be allowed to stand thus for 5 minutes; this is the time of infusion that is recommended by tea experts for obtaining the right degree of extraction of soluble components to give the best-quality beverage.

5. At the end of the infusion period, either the spent tea leaves should be removed or the beverage should be poured away from them into a utensil for serving.

⁴ For descriptive names applied to teas from other countries, as well as a more detailed account of tea grading, the student is referred to Ukers, W. H., *All About Tea*, The Tea and Coffee Trade Journal Company, 1935.

COCOA AND CHOCOLATE

In contrast to coffee and tea, the beverage made with either cocoa or chocolate is high in food value, owing both to the nutrients in the cocoa itself and to the common practice of using milk instead of water in preparing it.

Cocoa and chocolate are made from the fruit of cacao trees. These trees are indigenous to tropical South America, but, following upon recognition of the value of their fruit, they came eventually to be cultivated extensively not only in South American countries but in other countries, including Mexico and Africa. It is from cacao trees grown along the western coast of Africa that about two-thirds of the world's supply of cocoa and chocolate are now obtained.

The fruit. The fruit of the cacao, more commonly called cocoa, tree is a capsule ranging up to about 12 inches in length. When ripe it has a hard, leathery pod or rind inside of which are several rows of seeds, sometimes as many as 75 in number, embedded in white, pulpy material. These seeds are the cocoa beans from which cocoa and chocolate are made.

Manufacturing procedure. *In producing countries.* After the fruit is picked from the tree the pods are cut open, and the seeds with clinging pulpy material are separated from them and spread out in piles to ferment. During fermentation, changes occur, induced by yeasts and bacteria, which affect both embedding pulp and the seeds themselves as follows: the pulp disintegrates so that it can be easily removed from the seeds; various reactions take place in components of the seed which are accompanied by a lessening of their characteristic bitter taste, a development of desirable flavor, and a change in color of the seeds to dark red-brown. Following the fermentation step the seeds are washed, after which their water content is reduced by drying—either in the sun or by artificial means—until they become crisp.

In consuming countries. After this preliminary treatment in the countries where cocoa beans are grown, they are ready for shipping to various consuming countries where

further processing converts them into a variety of finished products.

The first step in the processing, irrespective of final product being made, is one in which the bean is roasted sufficiently to make it brittle so that the shell can be removed from the kernel or *cocoa nib*, as it is called. This roasting also causes further loss of undesirable bitter flavor and a development of desirable taste and aroma.

The cocoa nib comprises the part of the whole cocoa fruit that is made into the various familiar cocoa products. For these products nibs are crushed by a grinding action which converts them into a thick paste called "*chocolate liquor*." It is from this paste that final products are made as follows: (1) The paste is molded to make blocks or slabs of *bitter chocolate*. Or (2) it is sweetened and flavored, before blocking, to make various types of *chocolate bars*. Or (3) the paste is pressed to remove much of the fat, and the pressed cake is ground to make *cocoa*; the expressed fat is *cocoa butter*.

"Dutched" or "Dutch-process" cocoa and chocolate.

As the name implies, this process for manufacturing chocolate products originated in Holland. It is carried out essentially in the following manner: Cocoa beans are only partially roasted before the shells are removed. A solution of an alkaline material, potassium carbonate or other similar alkaline substance, is added to the nibs and the roasting process is then continued until water is completely evaporated, after which the nibs are ground in the usual manner.

In the alkaline environment, pigments in the nibs become darkened to give a chocolate or cocoa of a deeper and richer brown than is otherwise obtained. Dutch-process cocoa and chocolate are approximately neutral in reaction in contrast to cocoa products made without alkaline treatment, which are slightly acidic.

Components of cocoa and chocolate. All products made from cocoa beans contain the foodstuffs *starch*, *protein*, *fat* and *fat-like substances*, and *minerals*; they also contain

tannins and *pigments*; finally, they contain both *caffein*, but in negligible amounts, and a substance called *theobromine*, which, although related to *caffein* in chemical structure and present in considerable amount, does not have the same physiological effect.⁵

The chief difference in composition between *cocoa* and *chocolate* is in fat content. According to federal specifications chocolate must contain not less than 50 per cent fat, and breakfast cocoa—the kind commonly found in retail markets—not less than 22 per cent of this component. It is because of this difference in fat content that a chocolate beverage has a richer flavor and a more velvety consistency than that made with cocoa.

Preparation of the beverages. Since both cocoa and chocolate contain appreciable amounts of starch, and since the preferred method for preparing the beverages requires the inclusion of milk, cooking procedures necessitate a consideration of principles that apply to the cooking of both starch and milk.

For making cocoa. In preparation of the cocoa beverage, cocoa and sugar should be mixed thoroughly and blended with a small amount of water. These measures separate particles of cocoa powder with their embedded starch granules, thus providing for an extensive contact between starch and hot water when the mixture is allowed to boil; and boiling should be the next step in the procedure. During the boiling period starch granules become gelatinized (p. 45), some water is evaporated, and a thickened, almost sirupy, mass is obtained. At this point, cold milk should be added and the heating continued over boiling water—the approved method of heating milk—until the dispersion is hot and flavors have become blended. As a final step, the cocoa beverage is beaten vigorously in order to make a foam which prevents the formation of a surface skin (p. 149).

⁵ Goodman, L., Gilman, A., *The Pharmacological Basis of Therapeutics*. New York: The Macmillan Company (1941), p. 275.

For making chocolate. For this beverage, chocolate, broken or cut in pieces, should be mixed with sugar and cold water, after which the procedure is the same as in preparing cocoa. In this instance it is the gradual melting of the chocolate, as the mixture boils, that is relied upon to effect the necessary separation of starch granules.

Uses of cocoa and chocolate. Cocoa and chocolate beverages are popular in American dietaries. They are served frequently for breakfast in place of coffee or tea. Sirups made with cocoa or chocolate are of special value for contributing flavor when introduced into milk. Other cookery uses for these cocoa products are as ingredients for making candies, cakes, and desserts of various kinds.

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CHAPTER XXII

FOOD PRESERVATION

Importance. Food preservation includes all procedures whereby a food material is either placed in such an environment or else processed in such a way as to insure its keeping quality for a more or less indefinite period of time. *Nature* has various ways for accomplishing this end. Fruits, such as peaches and pears, are sealed within skins that are not easily penetrated by bacteria, hence the need for maintaining these skins intact and unbruised until the fruit is ready for use or for processing. In nature, too, grain seeds are thoroughly dried during ripening, thereby providing conditions unfavorable to attacks by spoilage agents and increasing the certainty that the seeds will serve their end toward producing the next harvest. *In the household and in commerce*, foods are either refrigerated, thus inducing a condition unfavorable to spoilage, or else they are effectively processed.

In modern times, various methods of food preservation serve as means for carrying food not only from season to season but also from places of abundant production to places of little or no production. As a result, food supplies are more nearly equalized in all parts of the country at all times during the year, and a wider variety of foods becomes available to all people at a moderate cost.

SPOILAGE AGENTS

The agents which are responsible for food spoilage and which, therefore, must be brought under control in all methods

for preservation of foods fall into two categories: *enzymes* and *microorganisms*. Preliminary items of general information in regard to these spoilage agents are as follows:

Enzymes. Enzymes are substances which are produced within living tissues of both plants and animals. They function as catalysts for reactions that are concerned with carrying on the life processes of cells. Enzyme activities continue even after the harvesting of fruits and vegetables and after the death of animals; and, unless controlled, these agents are in part responsible for some of the undesirable chemical changes that set in. For example: the oxidative destruction of both carotene and ascorbic acid (vitamin C) of fruits and vegetables, after their harvesting, is attributed to activities of enzymes in plant tissues. Enzyme activities are also responsible for the off-flavors which may develop in frozen and dehydrated vegetables and fruits during storage, and to some extent for the darkening of their cut surfaces when exposed to air.

Must be destroyed or effectively inhibited. From the viewpoint of food preservation, the most important factor that influences the functioning of enzymes is the temperature of their environment. For the duration of such low temperatures as are encountered in effective refrigeration or in freezing, enzyme activity is inhibited, but the enzymes themselves are not destroyed, since their functioning is resumed whenever favoring higher temperatures are again attained. Furthermore, enzyme activity increases with increasing temperatures until the environment approximates 158 to 176° F.; upon the maintenance of this temperature level, or even more effectively at higher levels, the enzymes are destroyed. This latter condition is made use of in modern methods of food preservation, since nearly all such methods submit the food to sufficient heat treatment at some point in the processing procedure to destroy any enzymes that may be present.

Microorganisms. The second class of spoilage agents includes the microorganisms *yeasts*, *molds*, and *bacteria*.

These unicellular organisms, as their inclusive class label implies, are microscopic in size. They are always present in air, water, and soil, and are thereby able to penetrate food materials. Consequently, any method of food preservation must include a treatment which either (1) *inhibits the activities* of microorganisms to such an extent that they cannot cause the food to spoil or else (2) it must *completely destroy* them.

✓ Yeasts. Although yeasts usually multiply by a process of budding, they perpetuate the species by means of *spores* with thick, resistant cell walls. Spores persist after budding has ceased. They remain dormant either when their environment is deficient in nutrients or when it is unfavorable for their development; then, when nutritional or other conditions—including temperature—become favorable, they germinate into actively growing cells.

Since yeasts utilize sugar in their life processes, and since they are tolerant toward acids, they are most troublesome when one is dealing either with sweet or with acid food materials. Hence, unless any yeasts present are destroyed, they cause spoilage in jellies and jams, also in sweetened canned fruits.

Temperatures that are most favorable for growth of yeasts are around 77° F. They are destroyed around 150 to 180° F., but *yeast spores* are more resistant.

Molds. These microorganisms are widely distributed in nature. Like yeasts, molds reproduce by means of spores which they make in great numbers and which are easily and widely scattered through the air. When mold spores lodge on food materials, they begin to grow, and the activities of the resulting molds are soon accompanied by spoilage. These spores do not require any special type of nutrient, therefore they develop into actively growing molds on all types of foods whether of plant or animal origin.

/ Mold spores are resistant to various adverse conditions, but, unlike spores from yeasts and bacteria, they do not present

any great problem in food preservation since, once they develop into molds, the latter can be seen and removed by skimming or cutting away portions of food involved; or, they (the molds) can be destroyed by heating the food to temperatures of from 150 to 180° F.

Bacteria. Bacteria are unicellular microscopic plants, and of all microorganisms they present the greatest problem in food preservation. Normally they grow by cell division, and in the actively growing state they are in the so-called *vegetative form*. But whenever their environment becomes unfavorable, many bacteria, like yeasts and molds, produce *spores* which are so highly resistant that they are able to survive until conditions again become favorable to their germination into the vegetative state.

Among adverse conditions which bacterial spores tolerate, while remaining dormant, are extremes of heat and cold, drying, and high concentrations of sugar, salt, or acids in the surrounding medium. Therefore, in successful food preservation, all of these conditions are taken into consideration.

GENERAL METHODS OF FOOD PRESERVATION

There are many methods of food preservation, but when one examines the principles which are involved in all of them, it will be found that the methods employed can actually be classified under only five headings: use of *cold*, use of *drying*, use of *sugar*, use of *salt* alone or together with other agents, and use of *heat*. The rest of this chapter is concerned with brief discussions of these five procedures.

1. Preservation through use of cold. As specified in the foregoing, low temperatures inhibit the activities of both enzymes and microorganisms, and spores become dormant; possibly, in some cases of extremely low temperatures, microorganisms may even be, in part, destroyed. This method of food preservation is taken advantage of not only in household refrigeration practice, but also in the refrigeration of foods during transportation, and during cold storage in warehouses.

In recent years, more effective and so-called quick-freezing methods have been developed which carry the foods down through freezing to maintain them, until used, at below-freezing temperatures (p. 315).

Effectiveness. It is a matter of common knowledge, however, that the preservation effect attained through only moderately cold temperatures, such as are achieved in household refrigeration of foods, is only temporary. On the other hand, foods that are processed by quick-freezing will keep in good condition for periods up to one year or longer—depending upon the character of the particular food concerned, and provided they are maintained at the extremely low temperatures involved.

2. Preservation through drying. *Blanching, a preliminary.* Prior to the drying process, it is customary with some foods to heat them either in hot water or steam long enough to destroy enzymes. This procedure is called *blanching*.

Microorganisms destroyed through osmosis. The drying of foods, whether accomplished by exposure to the sun or, mechanically, by passing currents of warm air over them, depends upon the principle of osmosis (p. 10) for the food preservation effect.

When tissues are fresh, the osmotic pressure of solutions within the cells of bacteria, yeasts, and molds and this pressure outside in the food dispersion (Fig. 16A) are at equilibrium. But when water is evaporated from the food dispersion, the concentration of salts and sugars is increased in this region, hence osmosis equilibrium is disturbed and water is withdrawn from the protoplasm of the microorganisms more rapidly than it is restored (Fig. 16B). A continuation of this disturbance results in the death of yeasts, molds, and bacteria that are present in the food mass, and their spores do not germinate in the dry environment established.

Store dried foods in closed containers. It is advisable to enclose dried foods in small, closely covered containers which should then be stored in a cool place. If containers are

small enough so that the dried food fills them, less air remains in contact with the food during storage, hence undesirable changes that result from oxidation of components are kept to a minimum. The use of closely covered containers is a wise

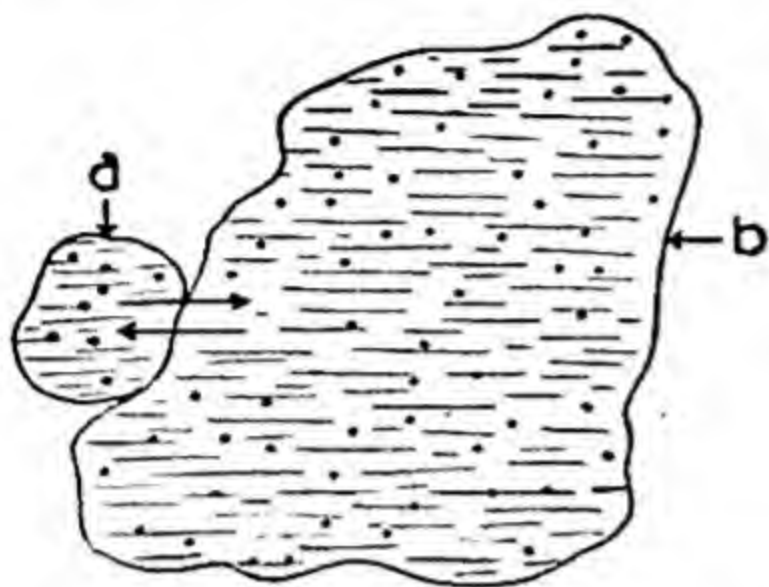


Fig. 16A. Fresh food tissue. In fresh food tissues osmotic pressure of solutions within bacterial cell (*a*) and in food mass (*b*) are equal, hence quantity of water leaving bacterium is equal to amount returned and no dehydration of bacterium occurs.

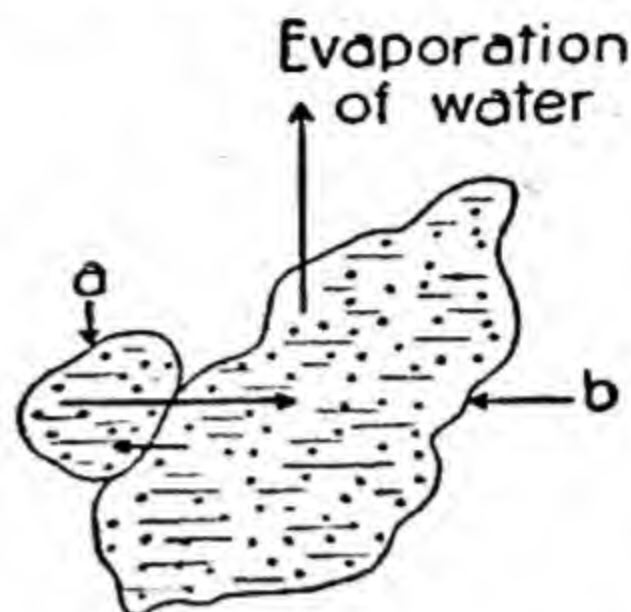


Fig. 16B. Preservation by drying. With water evaporating from food tissues (*b*) sugar and/or salts become more and more concentrated, hence osmotic pressure within the food becomes greater than that of solution in bacterial cell. As a result more water is drawn from bacterium (*a*) than is returned, hence the bacterium becomes dehydrated.

precaution, since even dried foods are quite likely to retain sufficient moisture to support the development of such yeast

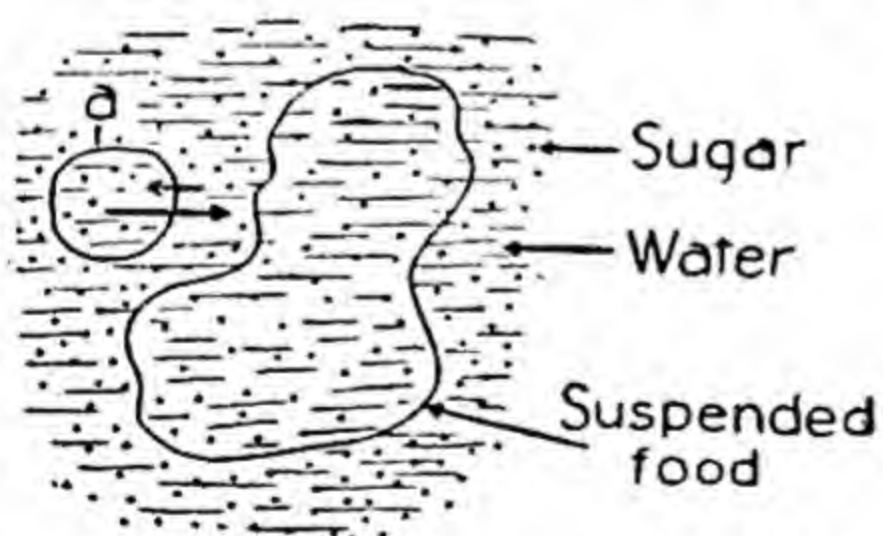


Fig. 16C. Preservation in high sugar or high salt concentration. Osmotic pressure of environmental solution is greater than that in bacterial cell (*a*) hence more water leaves bacterium than is returned and bacterium becomes dehydrated.

and mold spores as are permitted to settle on them from the air during the post-drying period. Finally, low temperatures inhibit all adverse changes due either to oxidation of food components or to the action of microorganisms that may have gained access to the food.

3. **Through the use of a high sugar concentration.** When sugar is present in high

concentration in the food dispersion that is undergoing processing—as in jellies, jams, and fruit preserves—the osmotic pressure of the sugar solution surrounding the microorganisms is so great that sufficient water is drawn from these bacteria, yeasts, and molds to cause their death (Fig. 16C).

Usually sufficient heat treatment is included in this method of preservation to destroy spores; if not destroyed, fortunately, they remain dormant in the unfavorable environment of a high sugar concentration.

Store in closed containers. Foods so preserved must be carefully sealed from contact with air so that air-borne yeasts and molds are not able to gain entrance.

4. Preservation through agency of salt. *Salt solution in high concentration.* Cucumber pickles and pork, processed in brine, are among the foods that are preserved in this manner. Salt in such high concentration—20 to 25 per cent by weight—is used that microorganisms are destroyed and spores remain dormant for the same reasons as when foods are processed in concentrated sugar solutions (Fig. 16C).

Keep well covered. Foods processed thus should always be well covered with the salt brine. Although air-borne yeasts may grow on the surface of the brine, they appear as a readily detected scum and can be removed by skimming. Entrance of yeasts can be partially prevented by keeping an appropriate covering carefully in place on the container used, which is frequently a large stone jar or wooden tub.

Salt in low concentration together with acids. Other varieties of cucumber pickles and sauerkraut, made from cabbage, are processed after this method. In this processing method the concentration of salt is so low—2½ to 5 per cent by weight—that, while the salt does contribute flavor to the food, the dehydration disturbance as to microorganisms is not sufficient to destroy them; hence other preservative factors must enter into the procedure.

This necessitates turning again to the osmosis disturbance,

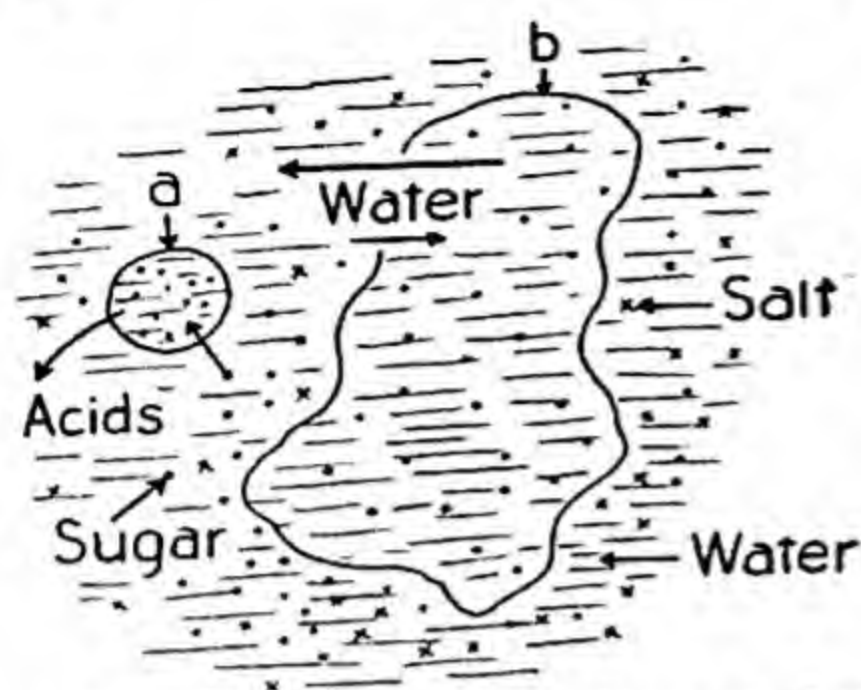


Fig. 16D. Preservation in low salt concentration. Some water and some sugar are drawn from food tissues (*b*). Bacterium (*a*) feeds on sugar to make acids, and acids in increasing concentrations produce unfavorable environment for continued bacterial activities.

sugar and *acids are made*. Eventually, as the reactions continue, an acid concentration is reached which is too great for continued bacterial activity.

Heated and put into containers. At this point the food is put into closed containers and processed in a boiling water bath (212°F.) as is done in canning (p. 300). This last step is not only further insurance of destruction of enzymes; it destroys yeasts and molds, as well as *bacteria in the vegetative state*. Spores are either destroyed or rendered dormant in the unfavorable acid environment.

Preservation by salts together with smoking. A method that is used for the preservation of some meats—such as hams—involves rubbing a mixture of salt (sodium chloride), saltpeter (potassium nitrate), and sugar thoroughly into the surface of the meat (p. 218) and following this treatment by controlled smoking. Salts dry the meat tissues, owing to the usual disturbance of osmosis equilibrium (p. 10) in the direction of continued removal of water from these tissues, as a result of which the meat fibers tend to harden. But, at the same time, the sugar has a slight counteracting effect,

not in this instance between bacterial cells and the surrounding solution, but between the food particles themselves—the cucumber or the cabbage, for example—and the surrounding salt solution. (Fig. 16D.) In these latter locations the difference in osmotic pressures is such that some water, also some sugar, are among the components drawn from the foods into the salt solution. When this occurs, bacteria feed upon the

since, as a peptizing agent (p. 367), it attempts to aid in maintaining the meat proteins in colloidal dispersion. The meat is finally surrounded by an atmosphere of smoke from smoldering wood, certain components of which have a preservative action in that they delay the activities of microorganisms. The kind of wood from which the smoke is obtained is a factor that affects the flavor of the dried meat. Many an old farm still possesses a "smoke house" in which the family supply of hams, bacon, and cuts of beef were formerly—perhaps in some instances still are—preserved in this manner.

Incidentally, the saltpeter, aside from its preservative effect, reacts with hemoglobin to make the red substance that is so characteristic of meat that has been cured by this means.

5. Preservation through use of heat. This method of food preservation depends upon the principle that exposure to high temperatures for adequate time either disposes of enough of the spoilage agents to extend the keeping quality of foods considerably, or else completely destroys, not only enzymes, but microorganisms and their spores. *Pasteurization* and *sterilization* are food processings that depend upon different degrees of heat treatment as follows:

Pasteurization. This involves a heat treatment that stops short of sterilization in order to alter food flavors and dispersion tendencies of natural proteins as little as possible. Obviously, the effectiveness of this treatment is limited and should be accompanied by other means of preservation: for example, pasteurized milk is commonly refrigerated in order to induce a *low temperature* unfavorable to the growth of undestroyed spoilage agents; the *high acidity* of such fruit juices as are pasteurized provides, in itself, an unfavorable medium for the growth of any lingering spoilage agents.

Sterilization. If the heat treatment is sufficient to destroy not only enzymes but all microorganisms, including spores, that are present in the food dispersion, the process is called

sterilization, and its effectiveness continues as long as the sterile condition persists. *The canning of food involves this principle of sterilization.*

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CHAPTER XXIII

CANNING OF VEGETABLES AND FRUITS¹

Definition. Canning is defined as the preservation of food by means of heat sterilization accompanied by hermetic sealing.

Extent of sterilization. *Complete sterilization* in the canning process is obtained by submitting the food that is undergoing processing to sufficient heat treatment to destroy *all* spoilage agents, namely: enzymes, yeasts, molds, and bacteria together with their resistant spores. The food is thereby rendered *completely* sterile, since it is free of all life.

Food processed thus, when in sterile, hermetically sealed containers, will keep indefinitely under any storage conditions.

Effective sterilization. Frequently, however, in order to avoid the possibility of overcooking, sufficient heat is applied to the food being processed to destroy enzymes, yeasts, molds, and vegetative bacteria but not enough to destroy all highly resistant spores. This treatment that is effective up to a point, but stops short of complete sterilization, is sometimes called *effective sterilization*. As with complete sterilization, the processed food should be enclosed in sterile, hermetically sealed containers.

The chances are good that effectively sterilized food will remain sound as long as it is *stored in a cool place*, since a low

¹ In general the principles that apply to the canning of vegetables and fruits apply also to the canning of meats. The student who is interested in this problem will find a discussion in *Home Canning of Meat*, AWI-110, United States Department of Agriculture, Bureau of Human Nutrition and Home Economics, 1945.

temperature is unfavorable for spore germination. But, in actual fact, home storage conditions are variable—sometimes a cool, shut-off place in the cellar, sometimes shelves or a cupboard in an open, furnace-heated cellar, sometimes top shelves in a warm kitchen. For this reason a completely dependable canning practice should have as a goal not effective but complete sterilization of preserved foods.

Classification of canning methods on basis of processing temperatures. There are several canning methods, but all include a step during which the food is subjected to heat at some prescribed temperature level for a given period of time. This heat treatment is called *processing*. And since heat-processing is the step in the entire canning procedure which sterilizes the food, the temperature level at which the heat is applied seems a logical basis upon which to classify canning methods. These methods have become standardized as: (1) processing foods at a temperature of 212° F. and (2) processing foods at a temperature of 240° F. It is a discussion of these methods with which most of this chapter is concerned.

Processing foods at 212° F. *Open-kettle method.* Processing foods by the open-kettle method is achieved by heating the food in an open kettle long enough to render it sterile, or at least effectively sterile (p. 299); it is then transferred into sterile jars and sealed with sterile lids. The temperature obtained in the food dispersion does not exceed the boiling point of water, at approximately 212° F., unless there is a significant concentration of sugar present (p. 7), which is not usually the case.

It is obviously essential that all technics involved in transferring the food into the jars and sealing them should be such that the sterile condition of food, jars, and lids is maintained in order to avoid recontamination of the processed food with air-borne organisms.

In closed containers at 212° F. When food is processed by this method, it is first packed into clean containers,

glass jars or tin cans, which are then either partially or completely sealed.² The containers with food are placed in a processing bath of boiling water, boiling under atmospheric pressure at approximately 212° F. During this procedure both food and containers are sterilized at the same time. At the end of the processing period all containers are removed at once from the bath, jars are sealed completely, and both types of containers are cooled with reasonable speed.

Processing at a temperature of 240° F. This method of canning food also involves processing it in closed containers, but in a pressure cooker³ in which the containers of food are surrounded by steam at the recommended temperature of 240° F. Details concerning the pressure cooker are given on page 309.

CONSIDERATIONS AS TO PROCESSING TEMPERATURES AND TIMES

Acidity of foods and sterilization temperatures. The temperatures which bacteria and their spores are able to withstand are influenced by several factors; but the factor of most importance in canning is the effect of the acidity, or the hydrogen ion concentration, of the food dispersion by which these spoilage agents find themselves surrounded.

In general, the *greater* the acidity of the food environment of bacteria and their spores—such as the high acidity provided by tomatoes and many fruits—the *less* is the resistance of these spoilage agents to heat treatment, hence their easier destruction. Contrariwise, the *less* the acidity of the food being processed, meaning the more nearly its reaction ap-

² Directions of manufacturers in regard to specific containers used should be consulted.

³ The large pressure cookers that are used for canning are frequently referred to as "pressure canners," a term which implies a limited use. However, these utensils can be used for cooking meats and certain vegetables and they always come equipped with inset pans for general cooking purposes. The more significant term, therefore, is pressure cookers. The smaller pressure-cooking utensils which are equipped with devices for obtaining steam temperatures greater than 212° F. are designated as pressure *saucepans*.

proaches neutral—such as the more nearly neutral reaction of all vegetables except tomatoes—the *greater* is the resistance of bacteria and their spores to increasing temperatures, hence their more difficult destruction.

It follows, then, that for their sterilization (1) *more acid foods*—typified by tomatoes and fruits—can be successfully *sterilized at lower temperatures*; while (2) *less-acid foods*—typified by snapbeans—should be *processed at higher temperatures*. A listing of a few foods according to their comparative acidities appears in the following table.

More-acid foods, processed at 212° F. in open kettle or water bath	Less-acid foods, processed at 240° F. in pressure cooker
Gooseberries Rhubarb Apricots Strawberries Peaches Pears Sweet cherries Tomatoes	Pumpkins Carrots Beets Snapbeans Spinach Asparagus Peas Corn Meats ⁴

Foods in the first category can be safely canned by any method which calls for a processing temperature of 212° F., which means by either the open-kettle procedure or in closed jars or cans processed in a *boiling* water bath.

Foods in the second category preferably require a treatment at temperatures *above* 212° F., hence a processing in a pressure cooker at 240° F. If, for any reason, these *less-acid* foods are processed at 212° F., the period must be greatly prolonged.

Processing times. But, important as *temperature* is in food preservation, another factor of great importance is the *time period* during which the temperature reached by the food

⁴ See footnote, p. 299.

dispersion is maintained. This must be the case, since, with foods of any given degree of acidity, *for effective sterilization* (p. 299) the lethal temperature must be continued throughout the food mass long enough to destroy vegetative bacteria and most spores, and for *complete sterilization* long enough to destroy bacteria and all spores.

Effect of temperature. However, in general, whether the food dispersion is highly acid or slightly acid, a longer processing of any given food at the lower temperature of 212° F. may have the same destructive effect on bacteria and spores as a shorter processing at 240° F. Even so, for the sake of assuring sterilization, if for reasons of convenience, *less-acid foods are* processed at 212° F., it is advised that state bulletins be consulted in regard to the length of processing time that is authoritatively recommended for each specific food.

Effect of heat penetration. In canning practice, as has been stated, it is essential that the food mass *in all parts* must not only reach the sterilization temperature but must be maintained at this temperature long enough to render it sterile. Therefore the speed with which heat penetrates into the center of the food mass affects the length of the processing period. Among conditions which influence this are concentration of starch present in the food and mode of heat transfer.

Concentration of starch. In foods which are characterized by a high starch content, such as corn, the speed of heat penetration is slower, therefore longer processing periods are required, than for foods lower in starch content, such as beets, for which shorter processing times are adequate.

Mode of heat transfer. When there is sufficient freely circulating liquid around the food within the jar for convection currents to be set up, the heat travels more quickly than in a dense pack in which it travels to some extent by the slower process of conduction. Consequently, the processing time is longer for a food which packs closely in jars than for a food the pieces of which are more or less separated by liquid. This is illustrated by the longer processing time required for spin-

ach and other greens which tend to pack closely, as compared with that required for more loosely packed snapbeans and beets.

Seek authoritative data from government publications. For dependable data on processing times and temperatures, as well as processing methods for various foods, one should consult publications of the United States Department of Agriculture⁵ and those of the nearest State Agricultural Experiment Station. The latter stress modifying local conditions that must be taken into account, such as the effect of altitude.

PRECOOKING—VENTING—VACUUM SEALING

Precooking and advantages. Details of canning differ for each type of food, such as more-acid and less-acid foods, or those that automatically form either loose or close packs; and bulletins, as recommended above, should be consulted in each instance. But a procedure which is common to the canning of almost all vegetables, also frequently used with fruits, is a *short precooking period* prior to packing the foods into containers for processing. This step has a number of beneficial effects:

1. A slight preliminary reduction of surface contamination of the fruits and vegetables is effected.

2. Cellulose structures are wilted, sometimes markedly as with greens, and some of the previously enclosed air is expelled from plant tissues. Both of these features make for a closer pack and contribute later to the formation of an adequate vacuum (p. 305) in the jar.

3. Some enzymes are destroyed, thereby establishing an early start in the minimizing of adverse effects of these spoilage agents.

Venting. In the early part of the processing period, when *closed* glass jars are the containers used, a phenomenon known

⁵ *Home Canning of Fruits and Vegetables*. AIS-64, United States Department of Agriculture, Bureau of Human Nutrition and Home Economics, 1947.

as *venting* occurs, which really means the step in the processing whereby some of the confined air and some water vapor are expelled from the jars. The explanation is as follows:

As the temperature of the food increases, the air within the jar expands and some of the water of the solution surrounding the contained food vaporizes. As a result, some of the expanding gases involved—air and water vapor—force their way out through the partial seal. Upon removal of each jar from the processing bath—boiling water or steam—the cover is tightened immediately by hand⁶ as the jar and contents begin the cooling-off process. As this cooling sets in, any air that remains within the jar contracts and the water vapor condenses; thus a partial vacuum within the jar follows (see vacuum sealing, p. 307)./

Creates a partial vacuum. A satisfactory partial vacuum is formed by venting, provided a precooking procedure is used and all air bubbles that are held captive between food particles are expelled during the preliminary packing of the jar, also provided adequate *head space* is left above the jar contents. Although directions differ as to the head space that is necessary, a good rule to follow is to allow 1 inch head space in a jar with a flat lid, and $\frac{1}{2}$ to $\frac{3}{4}$ of an inch space in a jar with a rounded lid.

Excessive venting is undesirable. *Reason.* Excessive venting is often encountered in home canning. It may result from the retention of too much air mixed with food within the jar, due either to inadequate precooking or to failure to so manipulate the jar contents, when packing, as to exclude all air bubbles entrapped between food pieces. Or, excessive venting may follow upon the vaporization of too much water from the solution surrounding food particles in the jar during processing.

Effect. But, whatever the cause, excessive venting results in the loss of so much water that some food rises above the

⁶ See footnote, p. 301.

solution in the jar. This portion of the canned food, during storage, dries out to some extent and darkens, as a consequence of which both appearance and flavor of the food are impaired.

Frequently occurs in jars processed in a pressure cooker. Excessive venting occurs whenever, due to careless manipulation of the pressure cooker (p. 310), the pressure of expanding gases—air and water vapor—within the closed jar is permitted to exceed the pressure of steam outside the jar (Fig. 17A). This should be avoided by proper pressure control, which calls for maintenance of an equality between

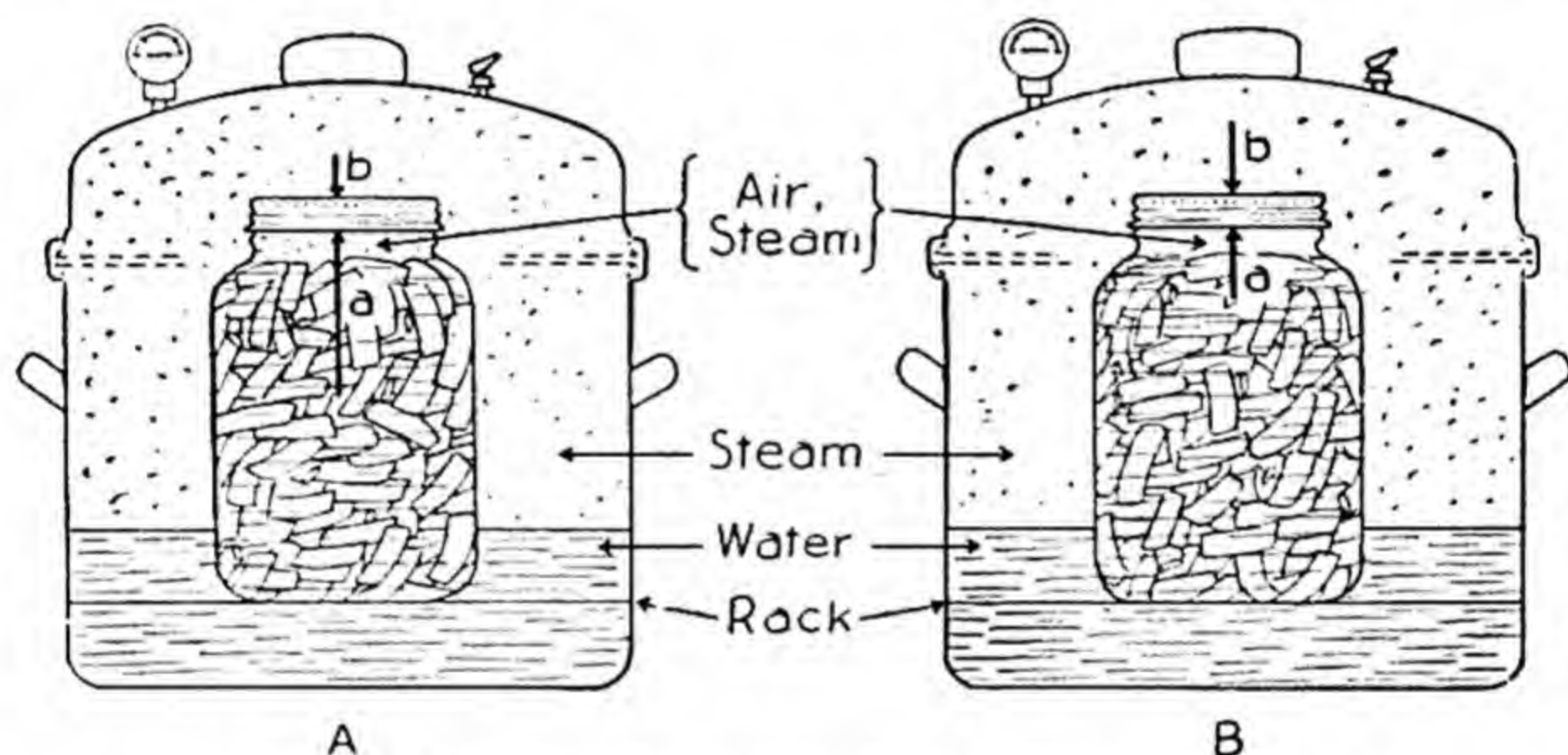


Fig. 17. Venting from jars in the pressure cooker.

A.

Excessive venting occurs when pressure of escaping gases (air and steam) (*a*) is greater than outer steam pressure (*b*).

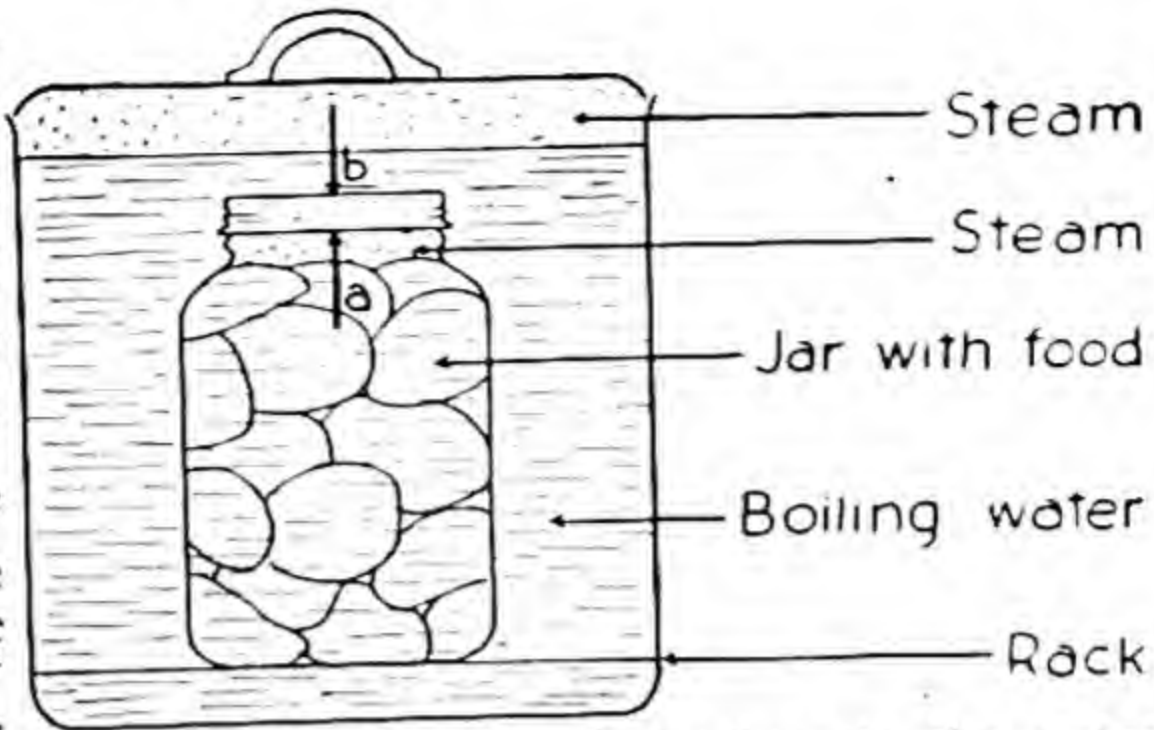
B.

Proper venting occurs when outer pressure of steam (*b*) is kept equal to that of escaping gases (*a*).

changing gas pressures within the jar and steam pressures outside in the cooker (Fig. 17B). This control should be continued, not only during the entire processing period but also, following this period, as the pressure in the cooker is reduced to atmospheric pressure just prior to opening for removal of the jars.

Does not occur in jars processed in boiling-water bath. There is no danger of excessive venting when food is processed

in jars in a boiling-water bath. In this method the pressure of expanding air and vapor inside each jar is, on the whole, automatically equal to the atmospheric pressure upon the surface of the boiling water outside the jar (Fig. 18).



In fact, venting occurs only during the early part of the processing period as some of the expanding water vapor and air escape, as the temperature of the contents is increased up to that of the surrounding boiling water.

Vacuum sealing. *Due to venting from closed jars* (p. 304). Establishing the partial vacuum due to venting is the final step in obtaining an hermetic sealing of the jar, thus making doubly certain that no entrance of air-borne spoilage agents shall become possible. This sealing is effected because the pressure of the atmosphere downward upon the outer surface of the lid exceeds the inner and upward pressure of confined gases against the lid's inner surface; and the lid is thereby pressed more firmly into place than can be achieved solely by hand-sealing (Fig. 19). Incidentally, atmospheric pressure (15 lb. per square inch) is one of the greatest pressure forces in nature.

In jars of food processed by open-kettle method. After food is processed in an open kettle, transferred quickly to sterile containers, and sealed as tightly as possible by hand, a further and more effective seal is established by the partial vacuum that is set up. This vacuum is the result of a contraction of the hot air and condensation of steam within the jar as it cools. Since no venting takes place from these jars, a lower vacuum is obtained than that produced in jars from

which venting has occurred, as discussed in the previous section.

PROCESSING EQUIPMENT AND ITS USE

For the open-kettle method. No special equipment is needed for the sterilization of food in an open kettle. Any



Fig. 19. Vacuum sealing. When jar is removed from bath and lid is tightened, enclosed air cools and contracts and enclosed steam condenses to water. Hence inner pressure (*a*) becomes less than downward pressure of atmosphere (*b*) on cover and a tight seal results.

kettle—iron, aluminum, or porcelain ware—will answer the purpose. While it is true that acids of food mixtures do react slightly with iron and somewhat more with aluminum (p. 347), in neither case are the salts that are made harmful. The colors of certain fruits, however, may be adversely affected. In using a porcelain kettle, one should be careful that it is not injured in such a way that chips of porcelain might become mixed with the food dispersion upon stirring.

For the water-bath method. For the closed-container processing method at 212° F. a water bath must be provided. This should be large enough to allow a space at the bottom of the kettle for a rack upon which to place the containers carrying the food, and at the top to give a depth of water above them of at least 2 inches. These conditions are neces-

sary in order that there may be *free circulation of boiling water around the containers* which, if glass, should be so placed upon the rack that they do not touch each other.

In using the water bath, in order to avoid breakage when glass jars are used, the water should be just below boiling when the closed jars with food are introduced. Since the temperature of the bath will immediately fall below this level,

the cover of the kettle should be kept in position only *loosely* until the water begins to boil, when it should be fitted tightly into place. By following this procedure one is certain to begin the count of the processing period from the instant the water begins to boil.

At the end of the processing period, the containers should be removed from the bath immediately and any necessary seal completed at once. A delay in sealing would permit entrance of air-borne microorganisms. It is also important to cool containers with contents, as quickly as is reasonably possible, down to such low temperatures as are unfavorable for development of any heat-resistant spores that may still persist within the processed food.

The pressure cooker. (For processing foods at temperatures above 212° F., a pressure cooker must be used. Water is put into the bottom of the cooker to a depth of about 2 inches, containers with food materials are placed on a rack, and the cover, which carries the pressure gauge, air valve (open at first), and safety device, is fastened tightly into place and heat is applied.

Pressure gauge reading should mean corresponding steam temperature. The pressure cooker is not equipped with a thermometer. Nor is a thermometer necessary, since, if the cooker is operated correctly, that is, with all air displaced from the cooker, there is a definite relationship between the pressure of enclosed steam and its temperature. Consequently: (1) when the space above the water, hence that around the containers, is saturated with steam—no air present—and (2) when the gauge is set accurately, each pressure-gauge reading is significant of a definite steam temperature, thus:

When space in pressure cooker is saturated with steam:

0 lb. gauge reading means steam pressure up to atmospheric

pressure, and steam temperature up to 212° F.

10 lb. gauge reading means steam at 239.4° F.

15 lb. gauge reading means steam at 249.8° F.

In order to obtain a space saturated with steam, *all* air must be driven out of the cooker by the steam before closing the air valve tightly. This means allowing steam to escape through this valve before it is closed for about 10 minutes, the exact time depending upon size of the cooker.

And, once again, the *pressure gauge must be accurate*, which means that it must be expertly tested frequently, otherwise it cannot be depended upon to indicate accurate steam temperatures within the pressure cooker and, as a consequence, sterilization conditions may be faulty. This must be the case even though all other technics in manipulating the cooker are carefully followed.

Slow reduction of pressure at end of processing. As has been explained under the discussion of venting from closed jars (p. 304), a steady maintenance of a constant pressure level within a pressure cooker throughout the entire processing period is essential. And at the end of this period a slow reduction of steam pressure to that of the atmosphere, before opening the cooker, is another essential feature of pressure-cooker operation. When jars are removed they should be sealed at once, and jar and contents should be cooled as speedily as possible.

As for *tin containers*, since they are hermetically sealed prior to processing, therefore not subject to venting, steam pressure within the cooker can be reduced quickly to that of the atmosphere when processing is completed.

For detailed directions. Detailed directions for the use and care of a pressure cooker are given in *government bulletins*. Also, in addition to these bulletins, it is always advisable to consult *manufacturer's directions* as to the operation of the specific type that is being used.

Effect of altitude. In processing canned foods other than at approximate sea level, the effect of altitude upon the boiling point of water must be taken into consideration and the necessary adjustments made in processing pressures and periods. For these adjustments, again, local state bulletins should be consulted.

SPOILAGE OF CANNED FOOD

Due to development of bacterial spores. Any spoilage which takes place in properly sealed canned food must be due to the presence of spores, so resistant to heat that they have survived the processing treatment and have developed into the vegetative state (p. 292). This must be the case since, during careful processing according to any method, all spoilage agents, other than very highly heat-resistant bacterial spores, are destroyed.

Among heat-resistant spores are those of certain thermophilic (heat-loving) bacteria which require temperatures of approximately 100° F. (and above) for growth, but remain dormant below this temperature. Therefore, the presence in canned food of such spores will not cause it to spoil if sealed containers with food are cooled quickly after processing (p. 301), then are held in a reasonably cool place such as a cool part of a cellar or cool pantry. On the other hand, (1) should the containers of processed foods be permitted to cool too slowly immediately after processing, or (2) should they be stored under conditions which make it possible for their contents to reach temperatures in the neighborhood of 100° F., then any undestroyed spores of such bacteria, if present, will inevitably develop into actively growing organisms and spoilage will set in.

Aside from these bacteria, whose spores remain dormant up to approximately 100° F., there are other thermophilic bacteria the spores of which, although they do develop more extensively at higher temperatures, are unfortunately able to advance into actively growing bacteria even at ordinary temperatures; hence the survival of such spores in canned foods presents a serious spoilage hazard. For this reason, in the processing of foods, spores of these bacteria must be completely destroyed, a condition which can be assured by appropriate adjustment of processing temperature and time.

Signs of spoilage. When spoilage does occur, both acids and gases are produced or just acids but no gases. The latter

type of spoilage—that is, when just acids are products—is spoken of as *flat-sour*. When gases are made they escape into the partial vacuum above the jar contents, where their increasing pressure results eventually in a broken seal.

Botulism. Even though encountered only occasionally, the most serious type of contamination in canned foods is that due to the presence of a soil organism called by the scientific name of *Clostridium botulinum*, but more conveniently abbreviated to Cl-botulinum.

These bacteria are rather widely, although irregularly, distributed throughout the country. Their menace lies in the facts that: (1) in any of the less-acid foods, such as snapbeans or spinach, the spores are so highly resistant that they can survive a temperature of 212° F. for several hours; and (2) of great seriousness, they can flourish and produce a deadly toxin at room temperature,⁷ hence at temperatures that are apt to be encountered during storage of canned foods.

This spoilage must be avoided. Thus, even though the probability of the presence of Cl-botulinum in foods, as they are gathered from the garden or purchased, is slight, the chance presence of the resistant spores of these bacteria is so serious a hazard that provision for their absolute destruction during food processing is imperative.

As recommended for destruction of other highly resistant bacterial spores (p. 292), this can be accomplished by the careful processing of food either at a high temperature (240° F.) for a shorter period or at a lower temperature (212° F.) for a *much* longer period. Of the two choices, especially for less-acid foods, it is a processing at the higher temperature which provides the better guarantee of spore destruction, hence the better protection against later spoilage. Furthermore, this is the *only* processing method for less-acid foods that is recommended by the United States Department of Agriculture and by some State Agricultural Experiment Stations.

⁷ Esselen, W. B., Jr., *Botulism and Home Canning*, Massachusetts Agricultural Experiment Station, Bulletin No. 426, 1945.

Precaution in preparation of canned food for table use. Spoilage from *Cl. botulinum* is usually manifested by formation of gases with offensive odors and by a soft consistency of the food. Foods in which these changes are apparent are automatically discarded. However, it is possible for the *toxin* to be present in a canned food which shows neither of these signs of spoilage. But, fortunately, the toxin with its lethal effect can be destroyed by heat. Therefore, for the sake of safety, in the preparation of canned foods of low acidity for table use, provided they have not been processed by the pressure-cooker method, it should be the *invariable* rule to bring the foods to the boiling point of approximately 212° F. and hold them there long enough for all pieces to reach this temperature throughout; five to ten minutes is usually adequate.

Should the boiling point in any locality not attain 212° F., as is true at high altitudes, the time of boiling should be lengthened. It would be well to consult the nearest State Agricultural College for recommendations in this regard.

Care of discarded food and containers. Canned food undergoing spoilage from this organism *must be burned* and the containers, *prior to washing*, must be boiled for 10 minutes in a solution in which 1/2 cup of washing soda is dissolved in each gallon of water.

Spoilage due to imperfect seal. The discussion thus far has not considered any spoilage that may occur in canned foods in instances in which the jar seals are imperfect and air can enter carrying microorganisms.

When this happens, any type of air-borne organism will grow which finds a favorable medium in the food concerned. Thus: *bacteria* will grow and multiply provided the food in the jars is of low acidity; *yeasts* will develop in canned fruits and fruit juices; and *molds* will grow in practically all canned foods (p. 291).

SUPPLEMENTARY READINGS

Home Canning of Fruits and Vegetables, AIS-64, United States Department of Agriculture, Bureau of Human Nutrition and Home Economics, 1947.

TANNER, F. W., *Microbiology of Food*, 2nd ed. Champaign, Ill.: Garrard Press, 1944.

CHAPTER XXIV

QUICK-FREEZING

Introduction. Quick-freezing of foods is the most modern of all methods of food preservation. Its origin lies in the work of Dr. Clarence Birdseye, who, when on a visit to Labrador, observed that fish and caribou meat that became frozen rapidly in that very cold environment retained their original flavor and tenderness for several months. Upon returning to this country, Dr. Birdseye took advantage of this finding to develop a process for commercial quick-freezing of fish; he thus became the pioneer in what is, today, a rapidly growing frozen-foods industry.

As a result, at the present time, methods of freezing have been so perfected and services so far extended, that among quick-frozen foods one finds not only fish, meat, and poultry, but also vegetables and fruits, and even a great array of food dishes either completely cooked or all ready for cooking.

Community lockers and home service. Although developments in commercial quick-freezing of foods have made such great strides in the short span of approximately twenty years since Dr. Birdseye's original work, of even greater interest is the increasing use of quick-freezing as a home method for preservation of foods. The original impetus to this practice has no doubt come about through the establishment in many localities of community freezing lockers to which individual families could, and still do, take home-grown products to be frozen and stored until time for use. But, at the present time, as was inevitable, equipment is being manufactured and

becoming widely available at a fairly moderate cost for freezing and storing foods right in the home itself.

Advantages of quick-freezing. Two reasons for the superiority of preservation of foods by quick-freezing over other methods are as follows: (1) Preparation of foods for quick-freezing is a comparatively simple, although painstaking, process. Also, (2) such frozen products more nearly resemble the original foods in general appearance, color, flavor, texture, and nutritive value than do those preserved by any other of the several methods in common use.

In contrast to slow-freezing. Quick-freezing can be defined as that method of food preservation whereby food is subjected to temperatures of from 0 to -40° F. under such conditions that it quickly becomes frozen throughout, and is subsequently stored at a temperature of 0° F. or below.

Essential conditions will be described more fully later (p. 319), but in the main they include placing small, compact units of foods either in direct or very close contact with the refrigerant or in a blast of cold air so that heat is rapidly withdrawn from them. Thus, quick-freezing differs from so-called sharp- or slow-freezing methods used formerly, and still used to some extent, which require many hours or even days for completion, owing to the fact that they apply to large units of food held in still air in refrigerated rooms maintained at temperatures ranging from as high as 15° F. down to -20° F.

Preserving efficiency. *Effect on enzymes and microorganisms.* It has been stated earlier (p. 292) that, in general, use of cold as a method of food preservation is possible because of the inhibiting effect of low temperatures upon the activities of spoilage agents—enzymes and microorganisms. Without destroying them, quick-freezing has an inhibiting effect upon enzymes. With respect to microorganisms, the exceedingly low temperatures involved not only inhibit their activities but even bring about some measure of destruction of such bacteria, yeasts, and molds as are in the vegetative (p. 292) state.

But some microorganisms do survive extremely cold temperatures; and this applies especially to spores, which are always quite resistant to adverse conditions. Even so, all microorganisms and their spores remain dormant as long as, but only as long as, low temperatures are maintained. It is for this reason that foods preserved by the quick-freezing method *must be kept frozen* until ready for preparation for the table; otherwise, activities of surviving microorganisms will increase and spoilage will follow.

Control of enzymes advised for vegetables and fruits.

In spite of the fact that the low temperatures of quick-freezing certainly inhibit activities of food enzymes, these agents still retain the ability to catalyze specific reactions to some extent even during freezing storage; as a result, changes in food components take place that are detrimental to the quality of frozen foods. This is particularly true in regard to *fruits and vegetables* in which such changes affect adversely the carotene and ascorbic acid content, also their color, flavor, and odor. Therefore, in freezing procedures for these two types of foods, measures should always be taken, prior to the freezing step itself, to destroy or effectively inhibit all enzymes present.

Enzymes destroyed by preliminary scalding of vegetables.

For vegetables, a scalding process, sometimes called *blanching*, either in boiling water or steam is used for destruction of enzymes. Conditions of scalding must be such that each piece of vegetable is equally in contact with the boiling water or hot steam. This is made possible (1) *with boiling water*, if a relatively large quantity of water is used to vegetable scalded—approximately 1 gallon of water to each pound of vegetable—and if boiling is sufficiently rapid to assure a thorough heating of all pieces of vegetable, or (2) *with steam*, if only a small quantity of vegetable is subjected to the steam treatment at a time, and if the receptacle in which the steaming is carried on is supplied with a tightly fitting cover.

The length of scalding period and the method employed should be adjusted to each particular type of vegetable; government or state bulletins can be consulted for this informa-

tion.¹ While the time of heating must be sufficiently long for destruction of enzymes, it must not be so unnecessarily prolonged as actually to cook the vegetable, or to cause any extensive leaching-out of water-soluble nutrients from the tissues into the scalding medium.

Immediately following the scalding process, the vegetable should be drained and either held under very cold running water or else plunged into a large quantity of ice water in order to chill the vegetable as quickly as possible before it is packaged.

In addition to its destructive effect on enzymes, scalding drives out air from plant tissues, thus rendering the vegetable less rigid so that it can be packed more effectively in the container for freezing.

Effective control of enzymes in fruits. When subjecting fruits to the quick-freezing process, preliminary scalding should not be used as a means of destroying enzymes, since it would alter the fresh character of the fruit. Instead, reliance must be placed upon the effective inhibition of enzyme activities by providing a *sufficiently high concentration of sugar*. For this reason, fruits are advisedly packed in either sugar or sugar sirup immediately after being washed.

Large fruits, after the order of apples, peaches, and apricots, that must be pared and cut—in contrast to small fruits such as berries—tend to darken at the cut surfaces while they are being prepared for packaging. This darkening effect is to some extent due to enzyme action, and in order to inhibit it, cut fruits can be placed in a *solution of citric acid* as soon as they are prepared: $\frac{1}{4}$ teaspoonful of citric acid to 1 quart of water is a good proportion of ingredients for this solution.

As a safeguard against any undesirable discoloration that may take place during freezer-storage, also during thawing, *ascorbic acid may be added* to such fruits in preparing them for the freezing process: $\frac{1}{4}$ teaspoonful of ascorbic acid to

¹ *Home Freezing of Fruits and Vegetables*, AIS-48, United States Department of Agriculture, Bureau of Human Nutrition and Home Economics, 1946.

each 1 or 1½ cupfuls of sugar sirup is recommended by the United States Department of Agriculture.²

The freezing process. Three stages. When subjected to the quick-freezing process, the food passes through three stages: a *cooling stage*, which carries the food down to the temperature at which stage two, or actual freezing, starts; the *freezing stage*, which for most foods lies in a temperature range between 31 and 25° F.; and a *sub-cooling stage*, during which freezing is continued and the food is carried down to 0° F. or below, when storage begins.

Freezing stage. During the freezing stage, a definite amount of heat, latent³ in water as liquid, is liberated as appreciable heat during the change of water, distributed throughout food tissues, from its liquid state to ice crystals. Therefore, if freezing of the food is to continue, provision must be made for increased chilling, in order to counteract the heat thus automatically released within the food mass itself. Also the refrigeration process must provide for a progressive lowering of the freezing point of the food mass as it becomes more concentrated with salts (p. 7), owing to continued freezing of water. This process should continue until a point is reached at which ice formation is practically complete.

Incidentally, some of the water which is frozen during this process is that which was combined with proteins in *gel* (p. 224) dispersion in tissue cells of the food. Hence the withdrawal of this water from this combination and the consequent dehydration of the protein *gel* is quite likely to be accompanied by a certain amount of protein coagulation.

² *Ibid.*

³ When ice at 32° F. melts to water, likewise at 32° F., a definite amount of heat (79.71 calories per gram of ice) must be used to accomplish this change in physical state. This heat energy used disappears as appreciable heat, and is seemingly "absorbed" by the water just to effect the change from solid to liquid, since no change in temperature is involved. This heat, latent as heat within the liquid water, is called latent heat of melting (or fusion). When the reverse change occurs, that is, when water changes from liquid to solid state, commonly called freezing, the liquid water gives up its latent heat (79.71 calories per gram of water), which becomes appreciable heat as solid water or ice appears.

The length of time it takes for foods to pass through the freezing stage depends both upon the water content of the tissues and upon the kind and amounts of solid components that are dissolved in this water. It will depend, also, upon the conditions of freezing to which the food is subjected, namely: degree of cold; size, shape, and compactness of package; care in packaging, which determines whether little or much air becomes entrapped; selection of packaging material with respect to its heat-insulating property; and closeness of contact between the food and the refrigerant.

Taking all of these factors into consideration, quick-freezing methods of food preservation have been perfected to such a degree that food passes through the freezing stage in from one to several hours, rather than many times this period, as is required in slower freezing processes.

As a result of rapid freezing, ice crystals, forming quickly throughout the food mass, are very small and, therefore, may have less tendency than do large crystals to rupture cell walls. Also, with more rapid freezing, the extent of alteration in the colloidal protein components of cells is apparently lessened to such a degree that upon future thawing some, at least, of the water is readsorbed.

These two peculiar effects of quick-freezing are reflected in the appearance and texture of the frozen product and are, therefore, factors in helping the food to retain its original appearance when thawed in preparation for use. These effects are also factors in reducing to a minimum a loss of water—called “drip” (p. 327)—from quick-frozen foods upon thawing, a loss which, if extensive, detracts from appearance of the food and involves some loss of water-soluble nutrients.

Methods of quick-freezing. All methods that are used for quick-freezing are designed to bring about rapid withdrawal of heat from the foods, thereby effecting such speed in freezing that the temperature of the food will fall through a range of from approximately 31° F. down to 25° F. in the

shortest possible time. In general there are four of these methods, a brief description of which follows:

Contact freezing. In the method called *single-contact freezing*, the food, either packaged or not, is placed on metal plates which are cooled from beneath by a circulating liquid refrigerant at sub-zero temperatures.

A variation of this method and one that is more efficient is *double-contact freezing*, in which foods, placed in flat packages, are brought into contact with cooling metal surfaces both above and below. Pressure is applied to bring even closer contact between package and metal surfaces.

Air-blast freezing. Various adaptations are used in air-blast freezing. The food, usually packaged, is sometimes placed on trays on freezing coils in a refrigerated room and cold air is blown over it. Or the food may be passed through a tunnel on a conveyor belt which is moving in a direction toward the origin of a blast of sub-zero air. Or it may be placed on perforated plates up through which a cold air blast is passing.

Spray or fog freezing. Unpackaged food is usually frozen by spraying it with a very cold liquid—brine or a sugar solution—as it rests on a wire mesh or a stainless-steel conveyor.

Immersion freezing. This procedure consists of immersing the food directly in the refrigerant at 0° F. Either sugar sirup, glycerine, or brine is used for the refrigerant, which is kept constantly agitated in order to accomplish a more efficient carrying-away of heat from the food. After removal of the frozen food from the liquid refrigerant, this product is centrifuged to free it from any excess of the refrigerant medium. The food is then packaged.

HOME FREEZING

Home freezers. Home freezers employ the *single-contact method of freezing*. In some cases these freezers are also equipped with a device to create an air blast. In order to

retain the cold and keep warm air out, such a freezer should have good insulating material sealed into the otherwise open spaces between the inner and outer surfaces of all walls and doors or lids; also all openings, such as doors or lids, should be fitted with gaskets and fasteners in order to insure tight closure. Finally, the freezer should be designed to maintain a temperature of 0° F. or below.

Several different types of home-freezing equipment are available, selection of which becomes a personal matter. However, in making a selection of a freezer, consideration should be given to such questions as: the size of the family to be served and whether the family is living in a farming, suburban, or city community; the amount of food to be frozen during any given period; and whether or not the food, after freezing, is to be taken to a community locker for storage. Individual manufacturers should be consulted for guidance in all of these respects.

Quick-freezing procedure.¹ For a successful home-freezing program there are certain important points that must be observed, irrespective of the product being frozen. A discussion of these follows.²

Selection of fresh food. Quick-freezing of food gives a product that is practically like the original fruit, vegetable, or meat. Therefore great importance lies in a selection of raw food of high quality. Indeed, it is inadvisable to spend time in the preparation of an inferior food, nor should valuable freezer space be used for freezing and storing it.

Vegetables are best frozen when they are ready for table use which, in some instances, as with peas, corn, and snap-beans, is just before full maturity. But *fruits* should be allowed to reach full stage of ripeness before freezing. In the selection of *both vegetables and fruits* consideration must also be given to the varieties concerned, since it has been found

¹ Acknowledgment is made to Miss Verna Miller, Director of the Home Service Department, Frigidaire Division, General Motors Corporation, for many points in technic that are mentioned in these sections.

that some varieties of vegetables and fruits lend themselves to quick-freezing better than do others. The Agricultural Experiment Station Bulletins of different states can be consulted for information in this connection.

As for a selection of animal foods for quick-freezing, emphasis should be placed upon choosing those which come from animals that are young and of excellent quality (p. 201).

Speed in preparation of foods for freezing. *Vegetables and fruits.* As everyone knows, the quality of all plant tissues deteriorates rapidly after harvesting. With vegetables there is a rapid loss of sugar, hence an accompanying loss in flavor. And with both vegetables and fruits there is an increase in surface bacterial infection, since there are always some microorganisms present on plant foods. It is obvious, therefore, that preparation of these foods for freezing should preferably take place immediately after they are harvested. If conditions are such that they must be held for any length of time, they should be placed in a refrigerator in order to keep undesirable changes at a minimum.

Speed in the actual mechanics of preparation of the food is also necessary, and this is made possible by preparing and packaging successive lots of food in small quantities. Packages should then be placed immediately in the freezing unit, or, if they are to be taken later to a community locker for freezing, they should, in the meantime, be placed in a refrigerator.

Meats and poultry. With animal foods, such speed in preparation for quick-freezing is not necessary. In fact, in freezing either beef or lamb, the carcass can be held in a cool place, at temperatures of from 33 to 40° F., for from 5 to 10 days prior to cutting up for freezing.⁵ This holding period allows the meat to ripen, a process which brings about certain tenderizing effects (p. 205) and enhanced flavor. But veal and pork should be frozen as soon as they are thor-

⁵ Diehl, H. C., and Warner, K. F., *Freezing to Preserve Home-Grown Foods*, United States Department of Agriculture, Circular No. 709 (1945), p. 18.

oughly chilled, which requires a holding of from 2 to 3 days.⁶ Poultry also is best frozen as soon as it is chilled, which is usually accomplished by holding it overnight at a temperature of from 32 to 36° F.⁷

Packaging of foods for freezing. Some foods may be frozen loose, that is, in individual pieces, as, for example, peas or cut-up carrots, and then placed in some sort of container that is designed for this purpose. Usually, however, food is packaged prior to freezing and this packaging technic requires great care. But whether it is a question of wrapping a cut of meat, or a chicken, with paper, or placing a vegetable or fruit in any type of container, the same five principles hold, as follows:

(1) If possible, *the size of the food unit* should be comparatively small; (2) *its shape* must be made as compact as possible; and (3) no more *wrapping material* should be used than is necessary. All of these measures allow for intimate contact of the food with refrigerating surfaces during freezing, so that heat can be rapidly withdrawn from it. In this respect, if containers are used instead of wrapping paper, those which are oblong in shape have an advantage over other types of containers, such as glass fruit jars, tin cans, or round fiber board cartons, although it must be admitted that these latter containers are frequently employed and with a good degree of success.

(4) In using any method of packaging, *the technic followed must be such that air is excluded* from between the food and the covering material, since the presence of air in contact with frozen food will, during storage, cause oxidative changes that are detrimental to appearance, flavor, and nutritive value. If paper is used for packaging and if the food is irregular in shape, such as chicken or a cut of meat, the paper should

⁶ Matlack, M. B., *Instructions on Processing for Community Frozen-Food Locker Plants*, United States Department of Agriculture, Miscellaneous Publication No. 588 (1946), p. 34.

⁷ Diehl, H. C., and Warner, K. F., *op cit.*, p. 27.

be molded closely around the food in such a manner as to exclude all air pockets.

(5) *Wrapping material*, whether package or paper, *must be "moisture-vapor" resistant* in order to prevent transmission of moisture from the food into the very dry cold air that surrounds it during freezer-storage. And, at the present time, there are a number of moisture-vapor resistant containers on the market as well as a variety of such papers for wrapping. If paper is used, in addition to its moisture-vapor resistant quality, it must be flexible and easily handled, and it must not crack as it is bent and molded into place around the food. Obviously, all *packaging material must be nontoxic, without odor*, and, for personal satisfaction, it should be *pleasing in appearance*.

Clear labeling. Each package of food should be clearly labeled with name and date of freezing. This practice will make for more efficient use of storage facilities, since clearly marked packages can be located quickly, thereby avoiding the necessity of holding storage equipment open for any undue length of time.

Freezing step. As stated previously, actual freezing should follow just as soon as is possible after the food is packaged. The special type of home-freezing equipment and the temperature at which it is adjusted for freezing are individual matters. However, in general, (1) if strict attention is paid to recommended packaging technics, (2) if packages are placed in close contact with the metal freezing surfaces, and (3) if manufacturer's directions are observed as to quantity of food introduced at any one time for freezing—then an environment in the freezer of 0° F. is considered to be sufficiently cold to bring about a rate of freezing that will yield a high-quality product, provided it is also properly stored. Actually, temperatures below 0° F. are preferable, but for home-freezing the added cost of maintaining these lower temperatures is considered unnecessary.

Storage. After the food is frozen, it is sub-cooled (p.

319) in the freezer to the storage temperature, and it should be held there while awaiting future use.

Conditions that prevail during this period of freezer-storage are of *great importance* in influencing quality of the food at such future time as it may be withdrawn for table use. For home use, a temperature of 0° F., *if steadily maintained*, has been found to be adequate for inhibiting those changes which, in spite of utmost care in the preparation of food for freezing, do occur. But since such changes are only inhibited, rather than stopped altogether, the length of storage time should be limited. In general, therefore, the advised time for storage of foods of both plant and animal origin should not exceed one year. Furthermore, from an economic viewpoint, a longer storage time than this need not be practiced, since one would not wish to hold any preserved food in storage beyond the time when it is again in season.

NUTRIENT LOSSES IN QUICK-FROZEN FOODS

In general. To begin with, let it be emphasized that losses in nutritive value that occur in quick-frozen foods are slight and that foods so preserved, then cooked, compare very favorably in this respect with the fresh product.

But, in general, losses that do occur are chiefly: (1) components that are soluble in water, such as sugar, salts, and water-soluble vitamins; and (2) ascorbic acid, which is the vitamin most liable to destruction by oxidation. Researches that have been undertaken with regard to nutrients and quick-frozen foods have been directed largely toward *vitamin retention and losses*.

Quick-frozen vegetables and vitamin losses. *During scalding and subsequent cold-dipping*, water-soluble vitamins may be leached out. Hence, it is essential that the scalding period be kept within the time limits recommended by authorities (p. 317) for each vegetable, and that the cold dip be as short as possible for adequate chilling of foods. *Scalding vegetables by steam results in less loss of soluble vitamins*,

as well as other water-soluble nutrients, than treatment with boiling water, but in using this procedure one must take great care to insure its complete effectiveness in destroying enzymes. Since carotene (provitamin A) is insoluble in water, it is not affected by scalding and cold-dipping of vegetables..

Incidentally, it can be assumed that any measures that reduce loss of water-soluble vitamins from vegetables will also reduce the loss of other water-soluble nutrients.

The actual freezing of vegetables, or for that matter of other foods, does not cause loss of components. But *during subsequent freezing-storage* some destruction of ascorbic acid and possibly of carotene may occur, especially if storage temperatures are allowed to rise above 0° F.

During thawing of quick-frozen vegetables, as sometimes happens prior to cooking, there is opportunity for loss through oxidation of ascorbic acid. This can be avoided, however, if vegetables are cooked without previous thawing, which is the recommended method.

During cooking of quick-frozen vegetables, the same conservation methods, as to nutrients, should of course be observed as in the cooking of fresh vegetables (pp. 239-251). It is true, however, that any tissue damage that may have been incurred during the freezing step is accompanied by the entrance of more soluble components into the cooking water than occurs with fresh vegetables; but, at the same time, this loss may, in large measure, be counteracted by the shorter period that is required to cook frozen vegetables that have undergone this tissue damage.

Slight nutrient losses with frozen fruits. In regard to nutritive value of fruits, the quick-freezing processes apparently do not present any problem. Fruits are not as a rule scalded or cold-dipped, and any liquid that comes from them during thawing is served with them, whether they are cooked or served raw.

Nutrients and quick-frozen meats. During thawing of meats, fish, and poultry, there is a certain amount of drip-

leaking of water from the tissues, and in so far as tissue components are dispersed in this water they will be lost from the food. However, quick-freezing methods as practiced today are such as to reduce drip to a minimum; also with meats and poultry, care can be observed to include this "drip" liquid in the gravy.

PREPARATION OF QUICK-FROZEN FOODS FOR SERVING

Fruits. Frozen fruits are as a rule served raw, and whether they are allowed to thaw completely or only partially is a matter of individual preference. The time required for thawing depends upon the temperature at which it is accomplished. Obviously, thawing takes place more rapidly at room temperatures than in a refrigerator; but a more even thawing throughout the package occurs if it is held in the cooler environment.

Vegetables. The recommended practice for frozen vegetables is to start the cooking while the vegetables are still frozen, dropping them into a small amount of boiling water, covering the cooking utensil, and keeping the time of boiling to a minimum. If the vegetable is one with stalks, such as broccoli, it may be thawed sufficiently, before it is placed in boiling water, so that the stalks can be separated, thus insuring a uniform degree of doneness. Aside from the beneficial effects of these procedures upon nutritive value, which has already been stressed, quick-frozen vegetables cooked in this manner are attractive in color, texture, and flavor.

Meat, poultry, and fish. In cooking quick-frozen animal foods, practices differ according to type of food. *With poultry*, a more even degree of cooking is obtained if the product is completely thawed before cooking is started. *Cooking of fish* should begin while the fish is still in the frozen state, hence several more minutes per pound should be allowed for its cooking than for unfrozen fish. The degree of cooking of fish can quite easily be judged by the texture of the cooked flesh.

Meats are allowed to thaw, or not, prior to the cooking period. Thawing may be carried out at room temperatures or in the refrigerator. If it is a large cut of meat, similar to a roast, about 2 hours per pound should be allowed for the thawing at room temperatures and 5 hours per pound in the refrigerator.⁸ Obviously, less time is required for thawing smaller cuts of meat. In all cases, meat should be thawed before the wrapping material is removed in order to avoid unnecessary contact with air.

In cooking meat that is completely thawed, the usual time schedule should be followed (p. 212). On the other hand, if it is still frozen when cooking is started, longer times than usual are required: about 12 to 20 minutes more per pound for roasts, and from 13 to 23 minutes longer for broiling thick steaks.⁹ A disadvantage that is encountered in roasting meats from the frozen state is that, even at low oven temperatures, outside portions of a roast become overdone before center portions reach a desirable stage of doneness. Also, without considerable experience, it is difficult to judge the exact time required for roasting. In fact, for such purposes, a meat thermometer is a distinct asset.

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⁸ Tressler, D. K., Evers, C. F., and Long, L., *Into the Freezer and Out*. New York: The Avi Publishing Company, Inc., 1946, p. 182.

⁹ *Ibid.*, p. 184.

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CHAPTER XXV

FRUIT JELLY

A perfect jelly. One could not do better in introducing this subject than to quote a description of a top-quality fruit jelly that is given in Goldthwaite's bulletin.¹ Thus, according to this authority, an "Ideal fruit jelly is a beautifully colored, transparent, palatable product obtained by so treating fruit juice that the resulting mass will quiver, not flow, when removed from its mold; a product with texture so tender that it cuts easily with a spoon, and yet so firm that the angles thus produced retain their shape; a clear product that is neither syrupy, gummy, sticky, nor tough; neither is it brittle and yet it will break, and does this with a distinct, beautiful cleavage which leaves sparkling characteristic faces. This is that delicious, appetizing substance, a good fruit jelly."

The fruit juice. Essential components. The juice of any fruit can be made into jelly provided that, in addition to its own peculiar coloring and flavoring components, which are so indispensable for an appetizing product, the fruit contributes an *acid* or *acids* together with the jellying factor, *pectin*. Moreover, the nature of these components must be such that they can be extracted from the fruit into its juice by suitable measures.

Variables in components. With variety of fruit. Fruits differ among varieties both in the kinds and concentrations of their *acid* components, as well as in their *pectin*

¹ Goldthwaite, N. E., *The Principles of Jelly-Making*, 5th ed. University of Illinois, Urbana, Ill., 1917, p. 3.

contents. For example: fruits that contain both pectin and acids in sufficient concentrations for making jelly include sour apples, crab apples, currants, wild plums, blackberries, cranberries, and some varieties of grapes; some fruits lack either pectin or acids—sweet apples, quinces, and pears contribute pectin but very little acids to their juices, while strawberries and rhubarb contribute sufficient acids but lack pectin.

With maturity of fruit. In general, the *acid content* of all fruits tends to decrease progressively from unripe to ripe to overripe stages; hence, from the standpoint of acid content, the need for using each fruit for jelly-making purpose at the just-right degree of maturity. Degree of maturity also has a direct bearing upon the *quantity of pectin* in a fruit as well as upon the quantities of closely related compounds, called pectic substances or pectic bodies. A brief discussion of these substances appears in the next section.

PECTIC SUBSTANCES

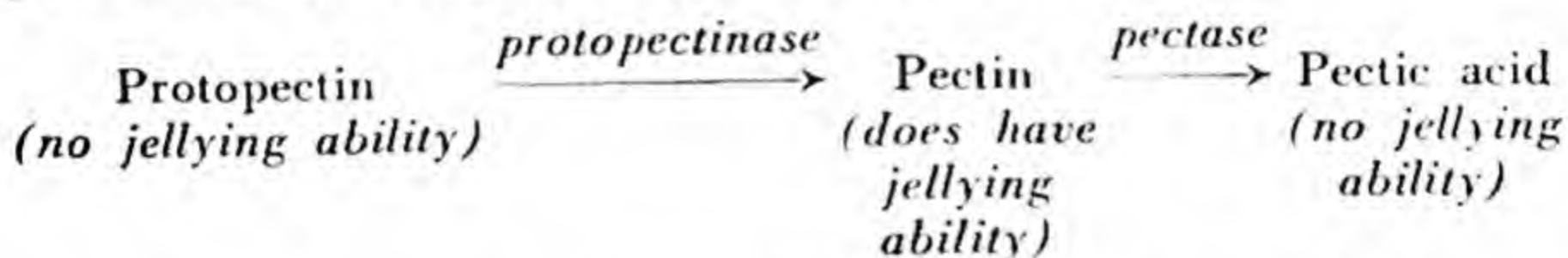
Three pectic substances. Pectic substances are designated as *protopectin*, *pectin*, and *pectic acid*. They comprise a group of closely related carbohydrate complexes that occur distributed in various parts of plants including the fruiting part. These substances are largely localized next to the skin and in between the tissue cells of the fruit, where some pectic substances, more especially the protopectin, function as cementing material to hold the cells together in their structural pattern.

Protopectin. This is the precursor of all other pectic substances. It is present in greatest amounts in unripe fruits, where it is more or less intimately associated with the cellulose that contributes to the containing membranes of fruit cells, and it also occurs as deposits on these cell walls. It is nondispersible in water, which doubtless accounts for its cementing effect in fruit structure; hence it follows that the greater the proportion of protopectin present, as is the case in unripe fruits, the firmer the fruit.

Being nondispersible, protopectin does not enter into colloidal dispersion; unlike pectin, it does not have jellying ability. Of final significance is the fact that, as its name implies, protopectin is converted into pectin.

Pectin. This pectic substance does form a colloidal dispersion and does have jellying ability; as has been said, it is made from protopectin, the reaction being catalyzed by the plant enzyme protopectinase. The change of protopectin to pectin takes place as fruit tissues mature; therefore, during the ripening of fruits, there is a decrease in protopectin and a corresponding increase in pectin. Accompanying this change there is some measure of separation of fruit cells from each other, which results in the familiar softening of fruits as they pass from unripe to ripe stages.

Pectic acid. Upon further maturing of the fruit, a gradual converting of pectin to pectic acid occurs, the reaction being hastened by the enzyme pectase. Like protopectin, pectic acid does not have jellying ability.



Proportion of pectic substances varies with degree of ripeness of fruit. It follows that the relative proportions of the three pectic substances that are present at any time must depend upon the exact stage of maturity of the fruit at the moment: in unripe fruits, as has been said, protopectin predominates; in ripe fruits pectin may predominate; and certainly in overripe fruits there is an increase in the quantity of pectic acid present.

Pectin from protopectin during jelly-making. These changes of protopectin to pectin to pectic acid, which nature brings about in the fruits through the agency of enzymes, can be effected by man by the simple means of heating with water any tissues in which pectic substances occur, or even more

effectively by heating such tissues with water which contains acid.

It is the latter method for increasing the production of pectin from protopectin that is taken advantage of in jelly-making; since, in brief, during the jelly-making process the crushed or cut fruit, which always has water as well as an acid or acids as components, is heated continuously (boiled) until the dispersion contains an optimum amount of this essential pectic substance.

Nature of pectin. From the foregoing it is obvious that of the pectic substances, pectin is of greatest interest in food concerns, since it is the only pectic body which, under appropriate conditions, precipitates as a jelly-like mass; hence it is the substance upon which the jellying ability of a fruit juice depends.

The exact chemical formula for pectin is not at present conclusively established; but it is believed that there are several pectin compounds so closely alike in chemical composition that they have very similar properties, including that of jellying. It is for this reason that reference in the literature is frequently made to pectins (plural) rather than using this term in the singular sense.

Pectin quality. Although the several pectins can all make jelly, they vary in their precipitating abilities. As a result, some pectins have a better so-called "pectin quality" for jelly-making than have others. However, there is little conclusive information on this question at the present time.

JELLY-MAKING

Selection of fruit. In making fruit jelly, selection of fruit is of great importance. Obviously the fruit must be one that contains sufficient amounts of protopectin and pectin to provide, eventually, a concentration of pectin in the extracted juice that will make possible the formation of a firm jelly. Also the fruit must be ripe enough so that it has good color and flavor, yet it must not be so ripe that the change from

protopectin to pectin and on to pectic acid has been carried too far. This means that the fruit must be of such ripeness as to be somewhat short in quantity of pectin ultimately desired. As already pointed out, the reason for this is that, in boiling the fruit to extract juice, not only is the *desired* reaction of protopectin to pectin continued, but also the *undesired* reaction of pectin to pectic acid. And, it must be remembered that pectic acid does not have the property of jelly formation.

Another factor that must be considered in the selection of fruit is the decreasing acid content with progressive ripening. This is of importance since the presence of acids is necessary, and in sufficient concentration, both for satisfactory extraction of pectin and for the later precipitation of pectin to form a jelly.

A rule for fruit selection. With all these factors under consideration—color, flavor, pectic substances, and acids—experience in jelly-making has shown that the best practice in fruit selection is to have most of the fruit at the fully ripe stage yet with some pieces slightly underripe: for example, some of the currants still not quite red, some of the blackberry “kernels” (called drupelets) red, not black.

With such a selection of fruit, one can feel fairly confident: (1) of having the pectic substances present in such a relationship as to provide eventually for the largest proportion of pectin for extraction; (2) of having adequate amounts of acid components to provide favorable environment for conversion of protopectin into pectin, and for later precipitation of pectin in the jelly (p. 236); and (3) of obtaining a jelly product of desirable color and flavor qualities.

Extraction of juice. With the fruit selected, the next step in the process of jelly-making is the extraction of the juice, which, once obtained, is a dispersion of pectin and other desired components—some, including pectin, in colloidal solution; others, including acids, in true solution. Preliminary to the actual extraction, the fruit is thoroughly washed. Next,

if it is *a hard type of fruit*, like apples, it should be cut into small pieces, care being taken to include all parts except the stems, since pectic substances are most concentrated in skins and cores. Then water should be added. If it is *a soft fruit*, such as currants and blackberries, it should simply be washed and mashed and possibly some water added.

The actual extraction which follows these preliminaries calls for boiling the fruit with added water for a period of time that is considered long enough² to convert some protopectin to pectin and to extract this pectin, together with that originally present, as such, in the fruit, into the surrounding dispersion. Long periods of boiling must be avoided as a precaution against bringing about any extensive conversion of pectin to pectic acid. It is apparent that other water-dispersible components of the fruit are extracted along with the pectin.

At the end of the boiling period, the fruit juice with extracted substances is separated from the nondispersible portion of the cooked mass, either by draining through some sort of bag made of fine-meshed cloth or by some other preferred device. The juice thus separated is largely water, but it contains a large proportion of the water-soluble components of the original fruit, and it holds pectin in colloidal dispersion.

Conditions for precipitation of pectin. *Acid and sugar necessary.* The exact process whereby pectin is precipitated from a colloidal sol dispersion to form a firm jelly-like mass in colloidal gel (p. 224) dispersion is not one upon which, at present, all authorities agree. It is a fact, however, that both hydrogen ions and sugar are necessary to bring it about.

Explanation: It is believed by some authorities that pectin is stabilized in colloidal *sol* state by adequate hydration (p. 364) of its micelles, but that hydrogen ions lessen the ability of the micelles

² Yeatman, F. W., and Steinbarger, M. C., *Home-made Jellies, Jams, and Preserves*, United States Department of Agriculture, Farmers' Bulletin No. 1800 (1945), Table I.

to hold this water of hydration in combination. Furthermore, it is believed that sugar acts as an actual dehydrating agent to remove from the micelles some of the water that is combined in this manner. As a consequence, in the presence of acids in sufficient concentration, and of sugar also in sufficient concentration, the *sol* state of pectin dispersion is disturbed as partially dehydrated micelles gather to form the larger aggregates of gel structure. And the gel structure holds captive all other components of the original fruit juice.

Concentration relationships exact. The rather definite relationship that must exist among the concentrations of pectin, hydrogen ions, and sugar in a *sol* in order for conditions to be right for *gel* formation is obtained by boiling the fruit juice with sugar added until, through evaporation of water, this concentration relationship becomes established.

It is probable that there is one definite concentration of pectin to hydrogen ions to sugar that provides optimum conditions for jelly formation and, therefore, for production of a perfect jelly. Even so, fortunately, there is a *range* of concentrations for each component within which a good fruit jelly can be obtained. Approximate figures for these concentrations are as follows: pectin, 0.5 to 1.0 per cent by weight of the dispersion as a whole; sugar, 60 to 65 per cent by weight of the dispersion or even up to 70 per cent in highly acidic juices; and sufficient acid to yield quite a high concentration of hydrogen ions.

As to pectin and acid. With respect to pectin and acids, one usually relies upon such a selection of fruits as is known to produce juice in which these two components are present in sufficient amounts. However, when making jelly, if the fruit should be lacking in pectin, either a small amount of a pectin-rich fruit or some commercial pectin may be included; if the juice should be lacking in acid, a small amount of lemon juice or tartaric acid may be added. To meet this latter deficiency Goldthwaite³ suggests 1 teaspoonful of powdered tartaric acid to 1 quart of fruit juice. However, experience in this practice will probably be the best guide.

³ Goldthwaite, N. E., *The Principles of Jelly-Making*, 5th ed., University of Illinois, Urbana, Ill., 1917, p. 12.

Concentration of sugar and pectin. Sugar is always an added ingredient in jelly-making, since fruits in themselves do not contain adequate quantities of this component either for satisfactory jelly formation or for desired sweetness of the finished product.

The amount that should be used with any given fruit juice to provide the best jelling conditions is directly proportional to its pectin content (see pectin tests below). Thus, any juice which, upon testing, is found to contain a relatively large pectin content will require the addition of relatively larger amounts of sugar than will a juice found to contain small amounts of pectin. Yet, if in either case too much sugar is used in relation to the concentration of pectin present in the juice, the jelly obtained from it will be too soft in consistency for desirable molding and, contrariwise, if too little sugar is used the jelly will be too stiff to be palatable.

Sugar and acidity. Acidity is another factor which influences the amount of sugar that should be used with a fruit juice in the making of jelly. From a theoretical viewpoint, the greater the hydrogen ion concentration of the juice, the less stable is the pectin sol (p. 224), hence the less the sugar that is required to cause the pectin to precipitate. But, actually, jellies so obtained—that is, from dispersions with high acid and low sugar concentrations—are apt to be undesirably stiff and lacking in sweetness. Therefore, in jelly-making practice, best all-around results are obtained if, as with sugar and pectin, direct relationships are also observed with respect to quantity of sugar added and acidity of juice.

Pectin tests. Since in the home it is not possible to determine the exact amount of pectin in fruit juices, certain tests have been devised to give an estimate of its concentration, thereby providing a basis for judging the quantity of sugar to use with any given juice. These are called *precipitation test* and *viscosity test*.

Precipitation test using alcohol. Either alcohol or Epsom salt, when added to a fruit juice, causes any pectin pres-

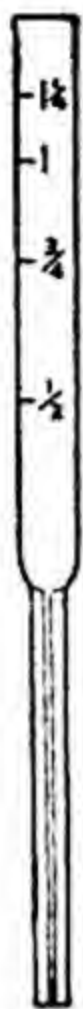
ent to precipitate in a jelly-like mass, and the quantity of precipitate together with its firmness are indications of the concentration of pectin in the juice. Procedure in applying the alcohol test is as follows:

Precipitation of pectin with alcohol. 1 teaspoonful of fruit juice is placed in a small dish, 2 teaspoonfuls of alcohol are sprinkled over it and the whole is gently mixed. After about 1 minute the precipitated pectin is examined. If there is a relatively large amount of this mass and if it holds together in one piece when suspended from the finger tips, the test indicates not only a relatively large amount of pectin present in the juice, but also a pectin of good jelly-making quality. On the other hand, if there is a smaller pectin precipitate and one which breaks into pieces when suspended, a smaller amount of pectin is indicated. Finally, if only a small and flocculent precipitate forms, there is very little pectin in the juice; in this case, before the juice can be used for jelly-making, it must be concentrated by boiling or, possibly, another juice rich in pectin mixed with it.

In the first instance, that is, with a juice rich in pectin, provided it is fairly acid, 1 or even $1\frac{1}{4}$ cupfuls of sugar should be used for each cupful of juice; in the second instance, that is, for a juice mediumly rich in pectin, only $\frac{3}{4}$ cupful of sugar should be used. These relationships are, at best, only approximate guides upon which to base sugar proportions, but with experience one can become fairly expert in interpreting them.

Viscosity test using jelmeter. A more accurate test of the jellying ability of a fruit juice, and thus the amount of sugar to use with it, is derived from a measurement of the viscosity of the juice. The principle involved is that the viscosity of a fruit juice is not only directly related to its pectin content but is also influenced by the quality of the pectin (p. 334). Therefore, juices of high viscosity are those with which relatively large amounts of sugar should be used. To measure viscosity of a fruit juice, hence its pectin content, Baker ⁴ has devised a jelmeter as follows:

⁴ Baker, G. L., "A new method for determining jellying power of fruit juice extractions," *Food Industries*, Vol. 6 (1934), pp. 305, 315.



Use of jelmeter. This useful piece of apparatus (Fig. 20) is a glass tube the lower part of which is very slender in diameter, while the upper half is much wider and is calibrated to indicate the measure of sugar to use with 1 cupful of fruit juice.

To operate the jelmeter, the entire tube is completely filled with juice which is then allowed to flow from it for exactly 1 minute, at the end of which time the level in the upper calibrated tube is noted. Since the rate of flow of juice through the tube decreases with its increasing viscosity, it follows that the higher the level of juice in the upper tube, the greater will be the proportion of sugar indicated for use. Directions for operating the jelmeter that accompany it when purchased should, of course, be carefully followed.

Fig. 20. Jelmeter.

Jelly-point and jelly tests. Drop test. It has been stated that in making jelly, in order to bring about the desired concentration relationship among pectin, acid, and sugar in the sol, the juice is boiled with added sugar. It should be emphasized, however, that in carrying out this step in the procedure the boiling should be carried only to the point at which the *sol* stage begins to merge into the *gel* stage of the dispersion. When this so-called jelly-point is reached, the boiling mass has become so viscous that when it is poured

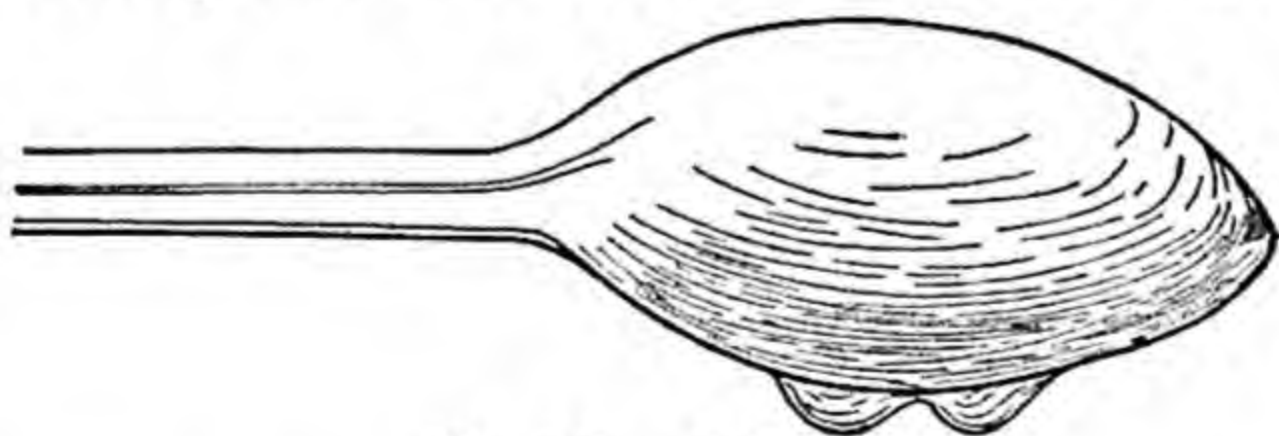


Fig. 21. Jelly test.

from a spoon the last portion forms *two* drops which tend to remain suspended from the edge of the spoon (Fig.

21). This constitutes the *jelly-test*, and with experience in jelly-making it can be judged with accuracy. When this test is obtained, the sol should be poured at once into hot jelly glasses which have been sterilized previously by letting them stand for about ten minutes in boiling water.

Supplementary test with thermometer. The above jelly-test should always be used, but if one has a thermometer, a temperature test can be employed as a supplementary check for the jelly-point.

The basis for this practice lies in the definite relationship that exists between the concentration of a sugar solution and its boiling point (p. 7). Accordingly, since the concentration of sugar in finished jelly lies somewhere in the range of from 60 to 70 per cent by weight, it follows that the temperature of the boiling sol at the jelly-point will always fall within a certain temperature range irrespective of the particular jelly being made. And this temperature range is approximately from 218 to 222° F.

CARE OF FINISHED JELLY

After jelly has been allowed to cool in the glasses long enough so that it has become at least slightly firm, it is ready for covering in order to exclude air with its spoilage organisms. Hot, melted paraffin is used for this purpose, and there are three important technics that should be followed in applying the paraffin:

1. The jelly glass above the surface of the jelly must be clean and absolutely free from splatterings of jelly, a precaution that should be observed as the hot sol is poured into the glass.

2. The paraffin, as said above, must be hot. Either a small tea-kettle or a saucepan placed in a shallow pan of boiling water can serve as a container for melting the paraffin.

3. As soon as the hot paraffin is poured over the surface of the jelly to a depth of about $\frac{1}{8}$ inch, the jelly glass should be rotated so that a film of paraffin will cling to the glass above the surface of the jelly and solidify, thus insuring an airtight seal.

Finally, the glasses with contained jelly should be labeled and then stored in a cool, dry place.

KEEPING QUALITY OF JELLY

During boiling of fruit for extraction of its juice, any *enzymes* present in it are destroyed so that they no longer con-

stitute a spoilage factor (p. 290). Then later, when the extracted juice is boiled with sugar, all *yeasts*, *molds*, and *bacteria in the vegetative state* (p. 292) are destroyed. Also, during storage of the jelly, its high sugar concentration does not provide a favorable environment for the development into the vegetative state of any spores that may have survived the boiling process, hence these spores remain dormant. Finally, the airtight paraffin seal prevents access of any microorganisms from the air.

But, obviously, jelly will not keep if the paraffin seal becomes loosened so that air-borne molds and yeasts can gain access and find favorable conditions for growth on its surface; hence the spoilage that frequently sets in over this area. Only slightly acid jellies are especially vulnerable to such attacks.

As specified, this spoilage hazard applies to yeasts and molds. Fortunately, bacteria which gain entrance to a jelly from air will not thrive due to the high sugar concentration involved.

SYNERESIS

Syneresis, as applied to jellies, has reference to the exuding of juice as the jelly stands unrolled in a dish, and it is a fault that is frequently encountered.

Although the exact cause of this phenomenon is not understood, it is liable to occur in highly acid jellies. Lowe⁵ states that the specific source of pectin must also be an influencing factor since, despite its high acidity, she has never seen syneresis occur in gooseberry jelly made from fruit juice of high acidity, or in jelly made from some citrus pectins that are precipitated from even more highly acid dispersions. Further discussion of this subject is beyond the scope of this text.

SUPPLEMENTARY READING

JUSTIN, M. M., RUST, L. O., and VAIL, G. E., *Foods*, rev. ed. Boston: Houghton Mifflin Company, 1940.

⁵ Lowe, B., *Experimental Cookery*, 3rd ed. New York: John Wiley & Sons, Inc., 1943, p. 172.

APPENDIX I

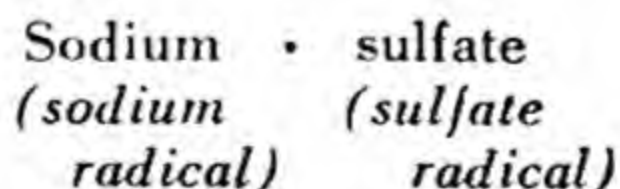
ACIDS—BASES—SALTS—IONS— HYDROLYSIS

The purpose of this appendix is to undertake a limited study of material which pertains: (1) to acids, bases, and salts—particularly to acids; (2) to ions obtained from molecules of these compounds in water solution—outstandingly to hydrogen ions; and (3) to hydrolysis of salts and of various compounds of food importance.

For more detailed information in regard to these subjects than is presented here, the student is referred to comprehensive chemistry texts.

ACIDS—BASES—SALTS

Constituent radicals. Acids, bases, and salts are composed of *radical parts*; that is, constituent parts which, although combined with each other, are in more or less loose combination and act as units within the compounds concerned. The salt, sodium sulfate, for example, is composed of the sodium radical and the sulfate radical, which, while combined with each other, function in certain ways as sodium and sulfate units within this compound:



Only four varieties of radicals contribute to the composition of acids, bases, and salts. They are: (1) the hydrogen radical; (2) the hydroxide (or hydroxyl) radical; (3) metal radicals; and (4) acid radicals.

An acid is composed of the *hydrogen radical* in combination with an *acid radical*. Examples are as follows:

<i>Hydrogen radical</i>	<i>Acid radical</i>	<i>Usual Name</i>	<i>Formula</i>
↓	↓	↓	↓
Hydrogen	chloride	Hydrochloric acid	HCl
Hydrogen	sulfate	Sulfuric acid	H ₂ SO ₄
Hydrogen	carbonate	Carbonic acid	H ₂ CO ₃
Hydrogen	acetate	Acetic acid	HC ₂ H ₃ O ₂

A base is composed of a *metal radical*¹ combined with the *hydroxide radical*, frequently called, also, the hydroxyl radical. Examples are:

<i>Metal radical</i>	<i>Hydroxide radical</i>	<i>Formula</i>
↓	↓	↓
Sodium	hydroxide	NaOH
Potassium	hydroxide	KOH
Calcium	hydroxide	Ca(OH) ₂
Magnesium	hydroxide	Mg(OH) ₂

A salt contains a *metal radical* and an *acid radical* combined with each other. The following are examples:

¹ There are a few radicals which, not composed of metal elements but of definite combinations between two non-metal elements, take the place of metal radicals in bases and salts. For this reason they are referred to as "metal-acting" radicals. Ammonium radical (NH₄), composed of the elements hydrogen and nitrogen, is the most important of the metal-acting radicals; it is a constituent of the base ammonium hydroxide (NH₄OH) and of many ammonium salts.

<i>Metal radical</i>	<i>Acid radical</i>	<i>Formula</i>
Sodium chloride		NaCl
Potassium phosphate		K ₃ PO ₄
Calcium carbonate		CaCO ₃
Potassium tartrate		K ₂ C ₄ H ₄ O ₆

Composition of radicals. As is indicated in the foregoing, the *hydrogen radical* (H) is composed of the one element hydrogen, and each *metal radical*, as with the sodium radical (Na), is composed of the one particular metal concerned. The *hydroxide (or hydroxyl) radical* (OH) is composed of oxygen and hydrogen in close combination. A few *acid radicals*, represented by chloride (Cl), are composed of the single elements respectively involved; but many acid radicals, of which the carbonate (CO₃) is an example, are composed of a non-metal element in combination with oxygen, the presence of oxygen being indicated usually by the ending *ate* in the names of the radicals; finally, many acid radicals, such as acetate (C₂H₃O₂), are composed of the elements carbon, hydrogen, and oxygen.

And, once again, when two or more elements comprise a radical, they are in close combination and act together *as a unit* within the compound and in reactions in which the compound becomes involved. This is the reason why hydrogen, when it is one of the two or several elements combined to make a radical, as in the hydroxide and acetate radicals, is quite different from the loosely combined hydrogen which constitutes the hydrogen radical in an acid.

Inorganic and organic acids. The acid components of foods are organic acids. This means that these acids are of plant or animal origin and that their acid radicals always contain carbon as one constituent element, usually in combination with both hydrogen and oxygen.² This is in contrast to inorganic acids, the acid radicals of which are built around a variety of non-metal elements including chlorine, sulfur, and

² A few acids, outstandingly carbonic acid, whose acid radicals contain the element carbon are classed as inorganic.

phosphorus. Contrasting examples of inorganic and organic acids are given below.

Inorganic acids

Hydrochloric acid	HCl
Sulfuric acid	H ₂ SO ₄
Phosphoric acid	H ₃ PO ₄
Carbonic acid	H ₂ CO ₃

Organic Acids

Acetic acid	HC ₂ H ₃ O ₂
Lactic acid	HC ₃ H ₅ O ₃
Tartaric acid	H ₂ C ₄ H ₄ O ₆
Citric acid	H ₃ C ₆ H ₅ O ₇
Oxalic acid	H ₂ C ₂ O ₄
Stearic acid	HC ₁₇ H ₃₅ CO ₂

Reactions between acids and metals. Acids are, of course, very widely distributed as components of numerous foods; therefore all reactions that tend to take place between these acids and metals of cooking utensils are matters of importance. It is in such reactions in relation to foods that this discussion is chiefly interested. But first it would seem appropriate and more intelligent to have a somewhat larger view of what reactions, in general, can be expected to occur from contacts between acids and metals.

In general. The chemist has learned that metals in re-

Metals in order of relative activities

Potassium
Sodium
Calcium
Magnesium
Aluminum
Zinc
Chromium
Iron
Nickel
Tin
Lead

[Hydrogen]

Copper
Silver
Gold

spect to reactions with acids—as is true also of all reactions in which metals participate—fall, very helpfully, into a definite order based upon their relative activities. Such a listing is given here which begins with potassium as the most active and ends with gold as the least active of the metals included. Hydrogen, although not a metal, appears in the position indicated because those metals which are listed “above hydrogen” behave, chemically, in ways that are quite different from the chemical behavior of “metals below hydrogen,” which leads to the fact of chief interest at this point, namely, that “metals above hydrogen” can be

expected to react with acids, more or less readily, to make gaseous hydrogen and salts of the metals and acids respectively concerned. This fact is briefly stated, and examples are given as follows:

Acid + Metal (above hydrogen) \rightarrow Hydrogen + Salt

Acetic acid + Aluminum \rightarrow Hydrogen + Aluminum acetate

Acetic acid + Iron \rightarrow Hydrogen + Iron acetate

Concerning reactions that involve the most active of these metals—potassium, sodium, calcium, magnesium—it will only be said here that with active or strong acids, such as hydrochloric acid, reactions are so violent as to be very dangerous to undertake; furthermore, even with inactive or weak acids, such as those of foods, reactions are sufficiently excessive as to render these metals impractical for any ordinary uses.

Acids of foods and metals of utensils. Outstanding among the acids of foods are tartaric, citric, acetic, and lactic acids—all of them weak acids; further, it will be noted that most of the metals used for making cooking utensils—aluminum, iron, nickel, tin³—are among the “metals above hydrogen” and that they vary in chemical activity from only fairly active aluminum to comparatively inactive tin. But regardless of activity, contact between acid components of food with any of these metals will be accompanied by reactions—more or less appreciable—to make gaseous hydrogen and salts. Thus:

1. When cooking a food with acid components in an *aluminum* utensil, very small quantities of aluminum salts of the acids are made—aluminum tartrate from tartaric acid, aluminum citrate from citric acid, etc.—and the salts become mixed

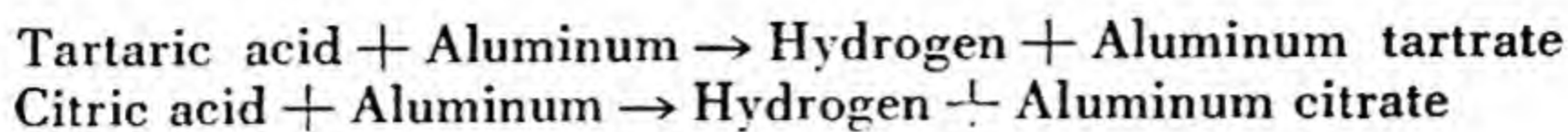
³ Nickel utensils are made of some other metal such as iron or copper, and plated with nickel.

Tin utensils are usually made of sheet iron covered with a layer of tin.

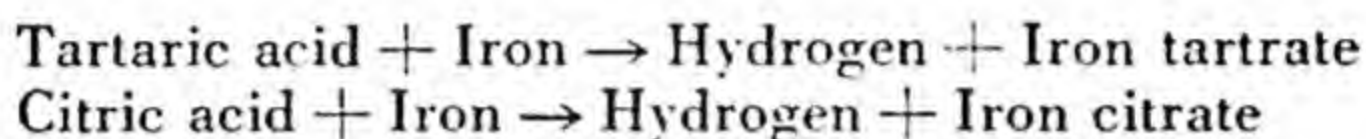
Stainless steel is an alloy of iron, chromium, and nickel.

Monel metal is an alloy chiefly of nickel and copper.

with the food mass; the hydrogen, formed slowly, bubbles out unnoticed.



2. With the same food mixture cooked in an *iron* utensil, since iron is less active than aluminum, not as much reaction occurs; but if contact is maintained for a sufficient length of time, appreciable quantities of iron salts are made, which, as always, mingle with the food mass.



3. When an acid food is cooked in either a *nickel* or *tin* utensil, due both to the general inactivity of food acids and to relative inactivity of the metals nickel and tin, reactions are so slight that negligible quantities of nickel or tin salts are produced.

Factors affecting reactions. All reactions between these metals and acids vary in extent depending upon: (1) the length of time the contact between acids and metal is maintained, (2) the temperature of the food mass in contact with the metal, and (3) the concentration of the acid or acids.

Effects of salt products. As said in the foregoing, the appreciable quantities of aluminum salts and iron salts, which may be made when foods with acid components are cooked respectively in aluminum and iron utensils, become mixed with the food mass concerned. *Aluminum salts* do not affect the flavor of the food to any extent; when ingested, if soluble—and some of them are soluble—they are absorbed from the intestinal tract, but there is no authoritative evidence that they are harmful. *Iron salts* are quite likely to have decided tastes, but their concentration in a food mass is slight; when ingested and absorbed they are not harmful; indeed they may even be beneficial as a source of iron element which is so

essential nutritionally and so sparingly provided for in a cross section of commonly used foods.

Acids of foods and copper utensils. Copper is the only one of the “metals below hydrogen” (p. 346) that is used for making cooking utensils; even then, the kettle or saucepan is usually lined with another metal such as chromium, nickel, or tin, in which case the problem becomes one of acid-foods with one or the other of these metals, not copper. However, should a copper kettle be unlined, so that acids of foods—tartaric, citric, acetic acids, etc.—are in contact with this metal for any length of time, especially at high cooking temperatures, reactions do take place and copper salts of the respective acids are products, although in low concentrations. Other products are made but reactions are rather complex and copper salts are the products of chief food concern.

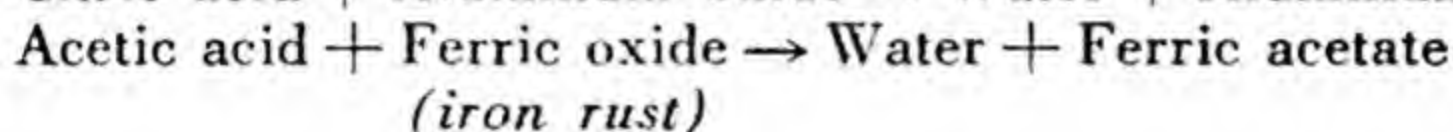
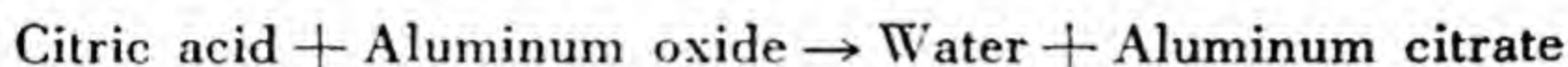
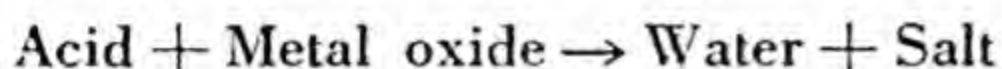
Effect of copper salts. The copper salts made from contact between food acids and copper metal are soluble and bluish in color. When ingested with the food mass, they are absorbed from the intestinal tract. While the absorption of a limited amount of copper salts may not be harmful, the continual use of unlined copper utensils for cooking purposes is not advised.

Food acids with rusted iron and dulled aluminum utensils. The substance called iron rust that collects on moist iron surfaces exposed to air is essentially *iron (ferric) oxide*; and the dull white coating that frequently forms slowly over an aluminum surface is *aluminum oxide*.

It is a well-known fact that when an acid-food, such as tomatoes, stands for any length of time in a dulled aluminum saucepan, the coat of aluminum oxide is removed. It is likewise true that, if any acid-food is held for a sufficient length of time in contact with iron rust, collected on the inside of an iron kettle, the “rust” will disappear.

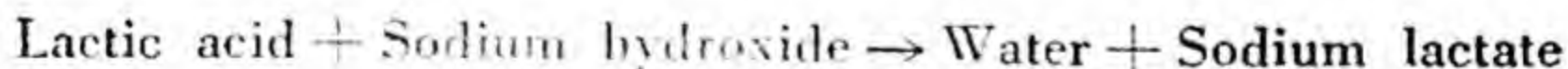
These reactions take place exactly as they should, because *acids react with metal oxides* and the products of each such reaction are water and the salt of the specific metal and acid

concerned. Therefore, tomatoes remove the dull coating from the aluminum saucepan because their several acid components react with the aluminum oxide to make the several aluminum salts—one of the acids is citric acid, hence one salt product is aluminum citrate. In like manner, vinegar removes iron rust from an iron kettle because its acetic acid component reacts with the iron rust (ferric oxide) and the salt product is iron (ferric) acetate.



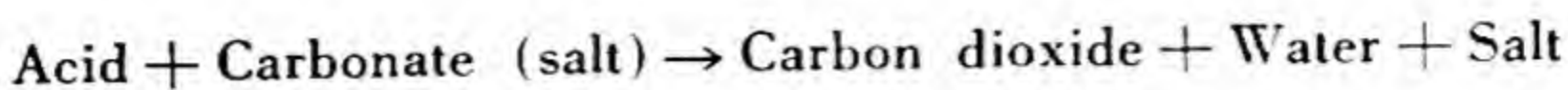
The aluminum and iron salts made during these reactions become mixed with the food masses; their effects are presented on page 348.

Reactions between acids and bases. Reactions of great importance in the various concerns of man are those which take place between acids and bases, and every such contact yields the same sort of products, namely, water and a salt, the salt product depending, as should be expected, upon the particular base and acid involved.

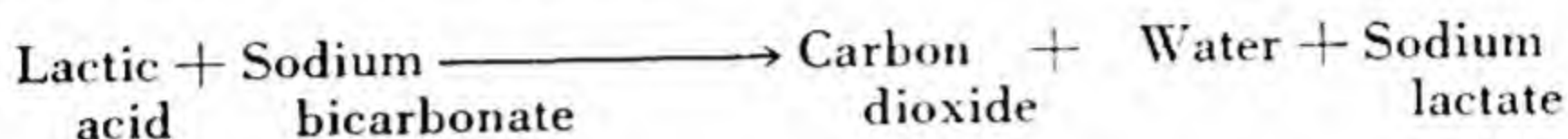


It is through such reactions that an undesired effect produced by an acid can be neutralized or destroyed by the introduction of a base; or vice versa, that an undesired effect due to the presence of a base can be neutralized by the introduction of a wisely selected acid.

Reaction between an acid and carbonate salts. Other reactions of considerable significance take place between acids and carbonate salts to make carbon dioxide, water, and other salts.



An example of such a reaction, and one of cookery importance, is that which occurs between lactic acid of sour milk and sodium bicarbonate for the purpose of making carbon dioxide for leavening various flour mixtures (p. 81). Word and formula equations for the reaction are as follows:



Classifications of salts. Salts are classified in various ways: on one basis they are classed as normal and acid salts; * on another basis they are classed as inorganic and organic salts. Making use of the information that is covered in the foregoing sections concerning radicals—those essential to the composition of salts and acids, also the difference between inorganic and organic acids—the distinction between these types of salts, now becomes possible.

Normal and acid salts. When a salt contains only radicals that are normal to the composition of a salt, namely, a metal radical combined with an acid radical, it is a *normal salt*; there are hundreds of these substances. But there are a few salts which, in addition to the normal radicals, contain a hydrogen radical; therefore such a salt contains a metal radical, a hydrogen radical, and an acid radical, and it is called an *acid salt*. Sodium hydrogen carbonate, also called both sodium acid carbonate and sodium bicarbonate, is a salt of this type; the prefix *bi*, as in the last mentioned name, is significant of the presence of a hydrogen radical “caught” among the salt constituents. The following are contrasting examples of normal and acid salts:

* There are also basic salts, but they have no importance in relation to foods.

Normal salts

Sodium chloride	NaCl
Calcium phosphate	$\text{Ca}_3(\text{PO}_4)_2$
Magnesium chloride	MgCl_2
Sodium carbonate	Na_2CO_3
Potassium tartrate	$\text{K}_2\text{C}_4\text{H}_4\text{O}_6$

Acid salts and various names

Sodium bicarbonate	NaHCO_3
other names {	Sodium acid carbonate
	Sodium hydrogen carbonate
Calcium biphosphate	$\text{Ca}(\text{H}_2\text{PO}_4)_2$
other names {	Calcium acid phosphate
	Calcium dihydrogen phosphate
Potassium bitartrate	$\text{KHC}_4\text{H}_4\text{O}_6$
other names {	Potassium acid tartrate
	Potassium hydrogen tartrate

Inorganic and organic salts. These two types of salts are based solely upon the character of the acid radicals concerned. If the metal radical of the salt is combined with an inorganic acid radical (p. 345), such as chloride or carbonate, the salt is an *inorganic salt*. If the metal radical is combined with an organic acid radical (p. 345), such as acetate or tartrate radical, then the salt is an *organic salt*.

Therefore, sodium, potassium, and magnesium chlorides and phosphates are inorganic salts; furthermore they are salts of food importance, they are widely distributed in plants, and it is from salts of plant sources that humans obtain the greater portions of these radicals for their nutritional needs (p. 153).

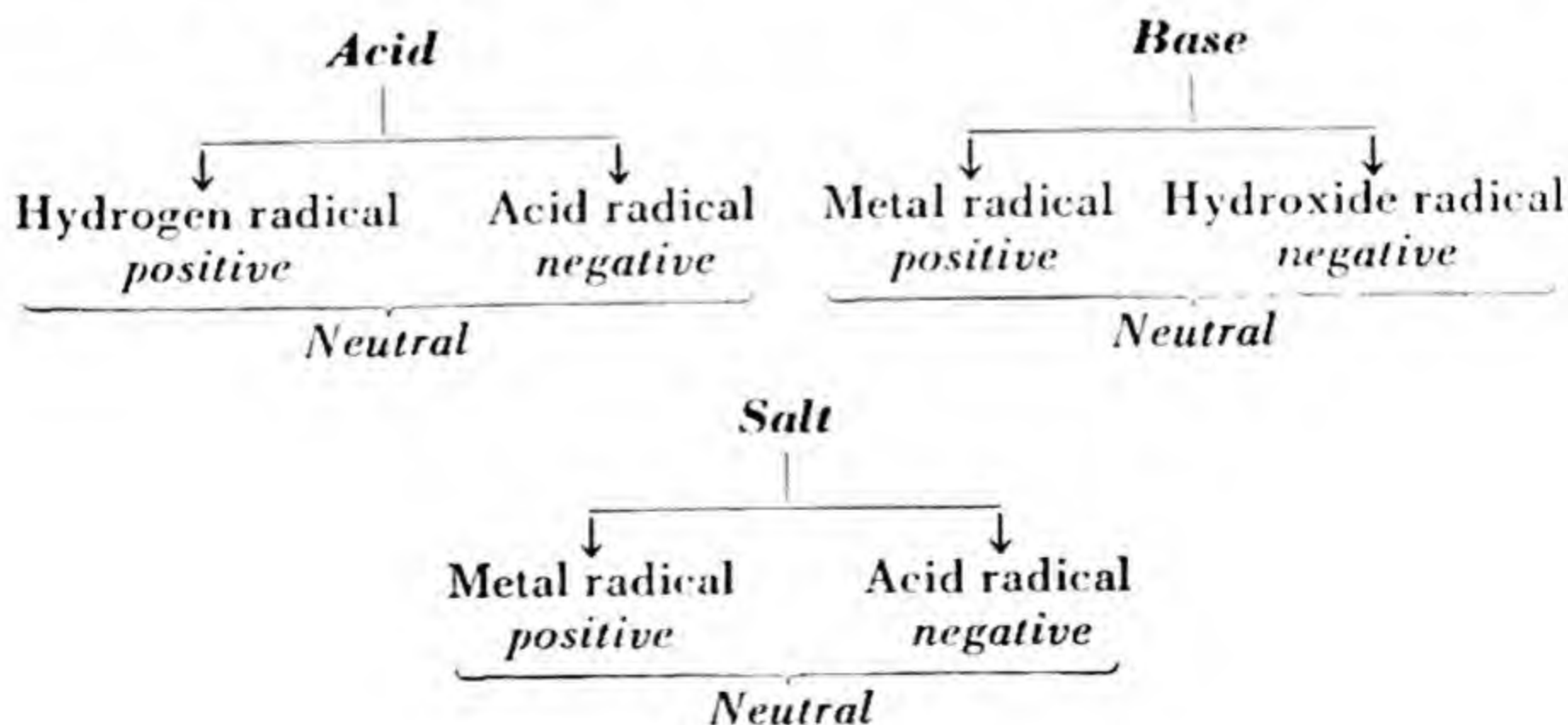
Organic salts have no especial significance in connection with foods. But soaps are organic salts, the usual soaps being mixtures of the salts sodium stearate, sodium palmitate, and sodium oleate (p. 124).

Esters. These substances, while not actually salts, are salt-like in some ways. There are two reasons for bringing them into the discussion here: first, fats, which certainly are of food importance, are specific esters—namely, esters which are composed of the glyceryl radical (C_3H_5) in combination with various fatty acid radicals; second, fats, as esters, engage in hydrolysis reactions with water in ways which are similar to the hydrolysis of salts. These reactions are discussed later in this section. Examples of esters are included in the accompanying summary.

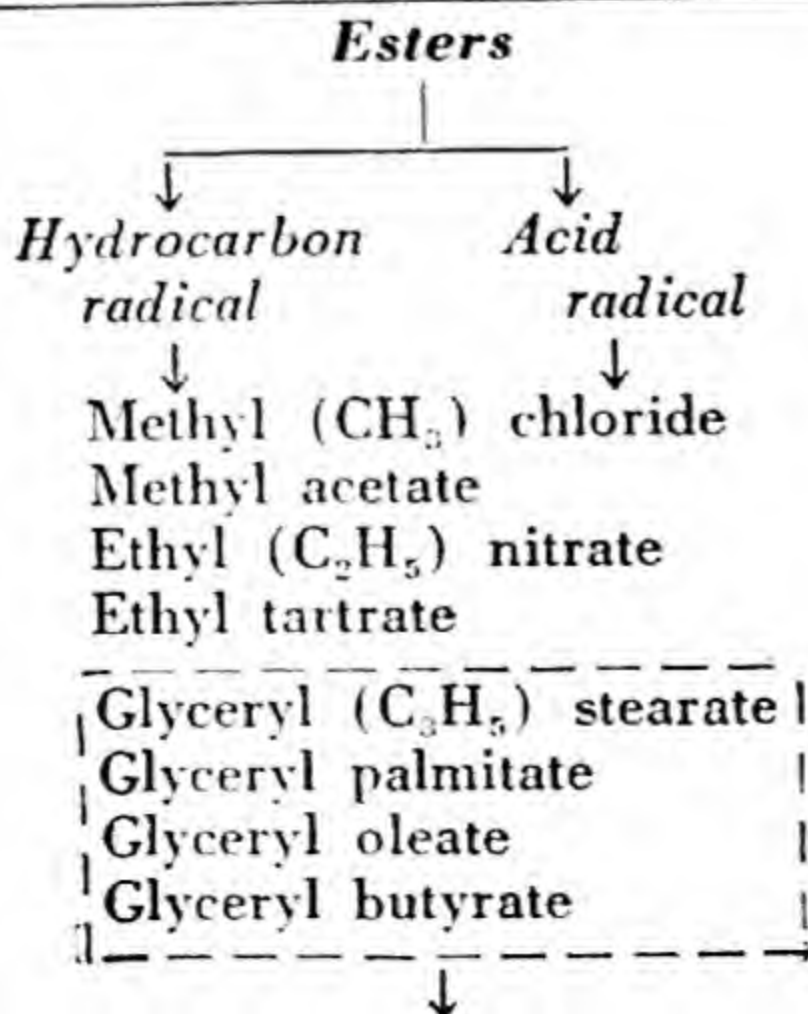
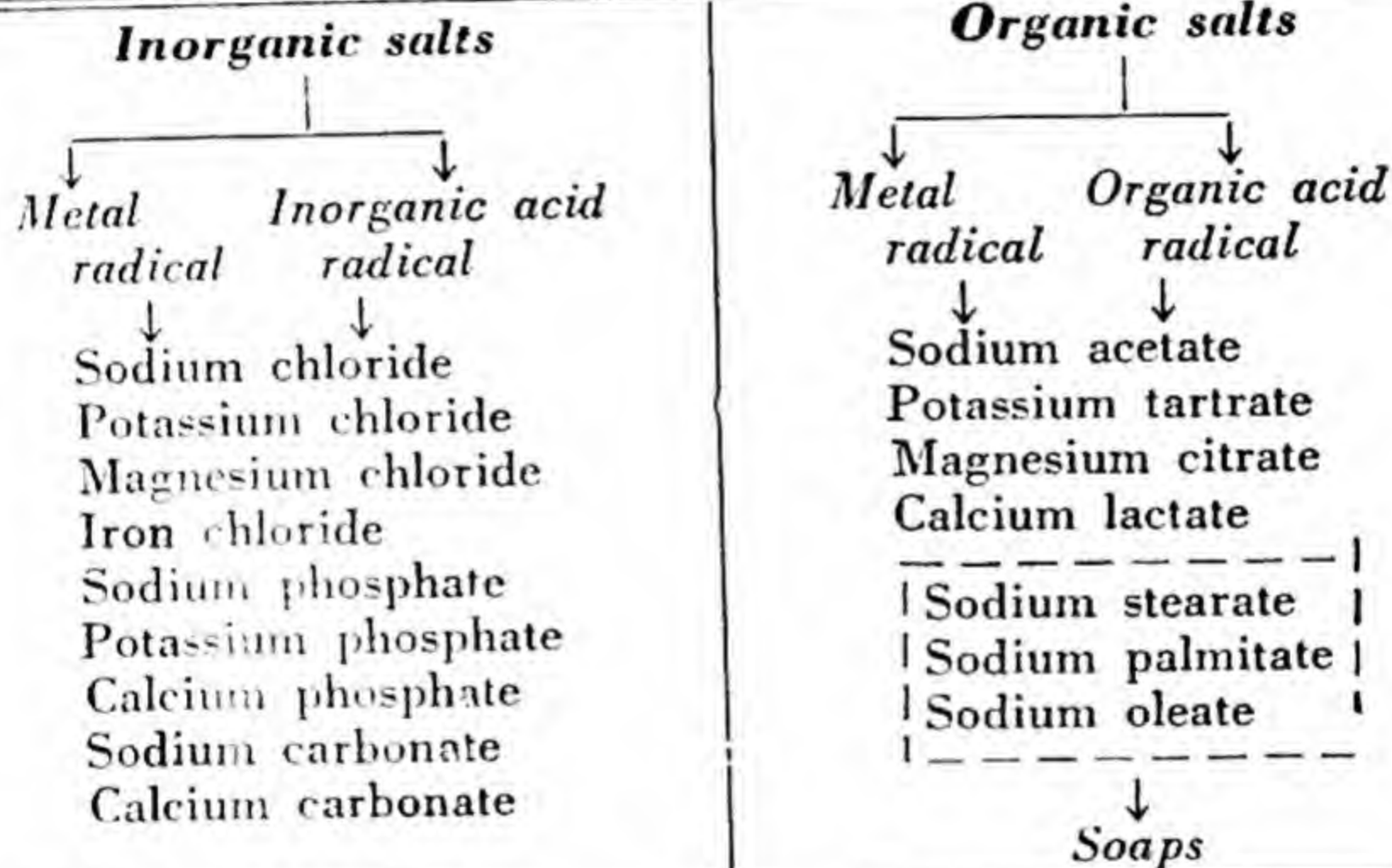
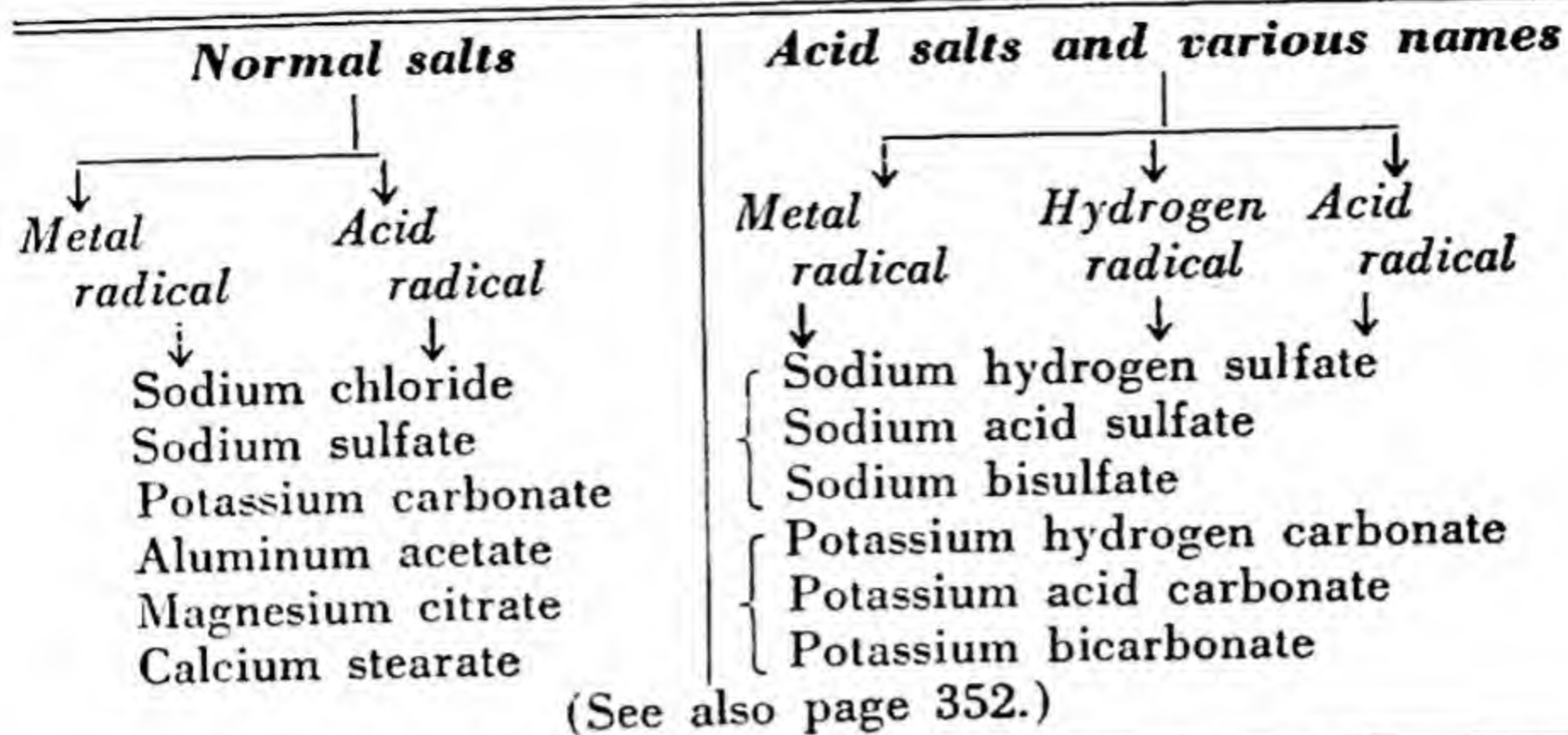
Composition of esters. An ester is composed of two constituent radicals: one of these must be a hydrocarbon radical, and there are many of them; the partner radical must be an acid radical, either inorganic or organic in character. Thus, methyl (CH_3) chloride and ethyl (C_2H_5) tartrate are both esters; and, as said in the foregoing paragraph, fats are specific esters in that they must all contain the specific hydrocarbon radical called glyceryl (C_3H_5) and the acid radicals must be those from fatty acids (p. 123).

IONS

Radical parts of acids, bases, and salts are electrically charged. It has not been necessary thus far to point to the fact that the radical parts of acids, bases, and salts are electrically charged. *In acids*, the hydrogen radical is positively charged, the acid radicals are negatively charged. *In bases*, the metal radicals carry positive charges while the hydroxyl radical is negative. *In salts*, metal radicals are



SUMMARY OF TYPES OF SALTS



positively charged, as in bases, while the acid radicals carry negative charges, as in acids. But in every one of these substances the quantities of positive and negative charges carried by the respective radicals are equal, so that *the acid, base, or salt as a whole is neutral*. These are *facts* as demonstrated experimentally with measurable amounts of these substances. (See page 353.)

Applied to molecules. Following from the foregoing it is reasonable to presume that each one of the millions of molecules that comprise any measurable quantity of an acid, base, or salt, is made up of two radical parts. But in a molecule a radical is a single atom or a closely combined group of atoms of the element or elements involved. Moreover, each atom or atom group must carry a charge which, although exceedingly minute, corresponds to the measurable charge on the related radical within large amounts of the substance. For example, it is believed that:

1. In a molecule of hydrogen chloride the hydrogen atom carries a minute positive charge and the chlorine atom an equally minute negative charge	}	represented thus $H^+ Cl^-$
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2. In a molecule of hydrogen sulfate each of the 2 atoms of hydrogen carries this minute positive charge, while the sulfate atom group carries 2 of these ultra-tiny negative charges	}	represented thus $H^+ \quad H^+ \quad SO_4^{--}$
--	---	---

3. In a molecule of sodium hydroxide the sodium atom is positively charged and the hydroxyl atom group negatively charged in these minute quantities	}	represented thus $Na^+ OH^-$
---	---	---------------------------------

4. In a molecule of sodium chloride the sodium atom carries such a positive charge and the chlorine an equally minute negative charge	}	represented thus $Na^+ Cl^-$
--	---	---------------------------------

As electrolytes their molecules are ionized. The familiar term, *electrolytes*, applies to acids, bases, and salts. These substances are electrolytes because, when in water solution, a greater or less proportion of their molecules are dissociated or ionized, that is, their charged atoms or atom groups have become separated from each other to form independent particles which are called *ions* or *ion molecules*. Thus:

1 Molecule

of Hydrochloric acid $\xrightarrow{\text{ionizes to}}$ 1 Hydrogen ion and 1 Chloride ion

$$\text{H}^+ \text{Cl}^- \longrightarrow \text{H}^+ + \text{Cl}^-$$

1 Molecule

of Sulfuric acid $\xrightarrow{\text{ionizes to}}$ 2 Hydrogen ions and 1 Sulfate ion

$$\text{H}_2^+ \text{SO}_4^{--} \longrightarrow 2\text{H}^+ + \text{SO}_4^{--}$$

1 Molecule

of Sodium hydroxide $\xrightarrow{\text{ionizes to}}$ 1 Sodium ion and 1 Hydroxyl ion

$$\text{Na}^+ \text{OH}^- \longrightarrow \text{Na}^+ + \text{OH}^-$$

Extent of ionization. The percentage of molecules that dissociate to form ions depends upon several factors, chief among which is the so-called *strength or activity* of the electrolyte. If the acid, base, or salt is strong (active), as are hydrochloric acid, sodium hydroxide, and sodium chloride, a high proportion of its molecules form ions in water solution. But if the acid, base, or salt is weak (inactive), as is true of acetic acid and other acid components of foods, only a low proportion of the molecules becomes separated into ions.

Most salts are strong, and all or nearly all of the molecules of a strong salt, such as sodium chloride, are dissociated into ions.

Ions and foods. Concentrations. The ions that are present in food dispersions—fruits, vegetables, meats, milk—are *hydrogen ions* from acids, *metal ions* from salts, and *acid radical ions* from both acids and salts.⁵ But their concentra-

⁵ Appreciable amounts of hydroxyl ions are present in a food mass only as indirectly formed when sodium bicarbonate is used (p. 82).

tions are never high. The acids are organic acids and weak, hence more molecules are un-ionized than ionized; also the acids as supplied by foods are in low concentrations. The salts present are *very* dilute, so, while strong and highly ionized, their ions are relatively far apart.

Effects of ions in foods. The sour taste of various foods is attributed to the presence of hydrogen ions. Some of the metal ions and acid radical ions also contribute characteristic tastes.

But, owing to the *charges* which they carry, ions in food masses produce effects that in some instances are desirable and in other instances not desirable; as a consequence the presence of ions, at times, becomes a cookery problem. For example: proteins of milk remain dispersed in the very low—almost neutral—hydrogen ion concentration of fresh milk; but when these ions reach a sufficiently high concentration, formed from dissociation of lactic acid made as milk sours, milk casein gathers into curd-like aggregates and precipitates—a familiar phenomenon in sour milk and in making of cottage cheese. Tomatoes have a relatively high acidity or high concentration of hydrogen ions, that is, as compared to the concentration of these ions in other vegetables; hence, cookery techniques that are used in preparing food mixtures in which tomatoes and milks are to be brought together involve the problem of making this contact and, at the same time, preventing the precipitation of milk proteins.

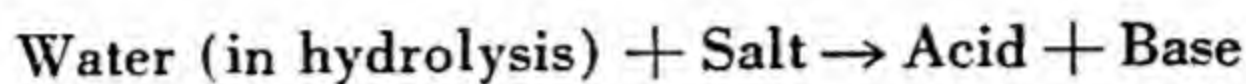
Hydrogen ions are extremely potent ions; therefore, such cookery problems as have a direct bearing upon their presence, also upon the presence of other ions, are considered at pertinent points throughout this text.

HYDROLYSIS

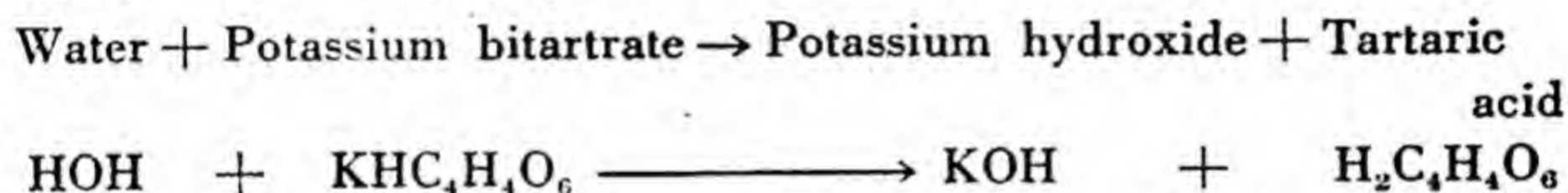
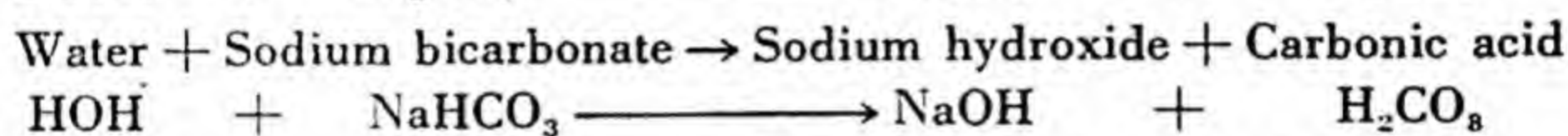
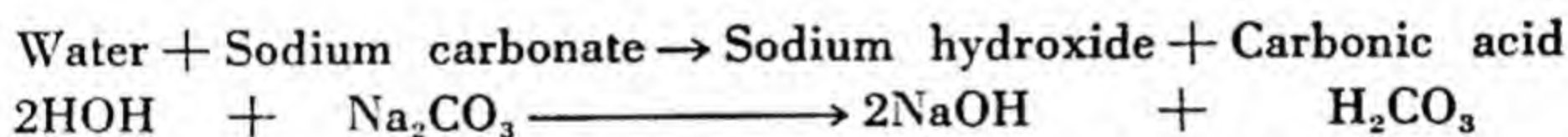
What is hydrolysis? Hydrolysis is a reaction between water, acting as hydrogen hydroxide ($H\cdot OH$) with various substances that are composed of radical parts (p. 343). The type of reaction is called *double decomposition*, which, put more simply, is a “change of partner” reaction on the part

of the radicals comprising the two reacting substances. This is exemplified in equations for typical reactions given in the following section. Hydrolysis reactions take place between water and certain salts, water and carbohydrates, water and fats, and water and proteins.

Hydrolysis of salts. When water and a salt engage in a hydrolysis reaction, the products are an acid and a base:



Among the salts which react with water in this way are those whose metal radicals are from strong bases and whose acid radicals are from weak acids; they include sodium carbonate, sodium bicarbonate, and potassium bitartrate or cream of tartar.

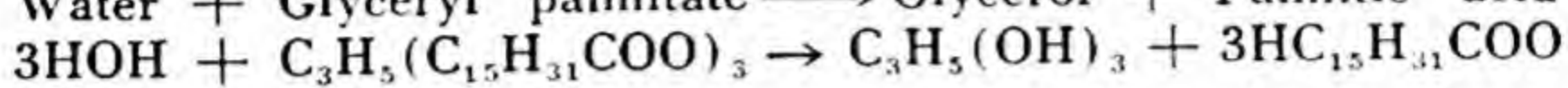
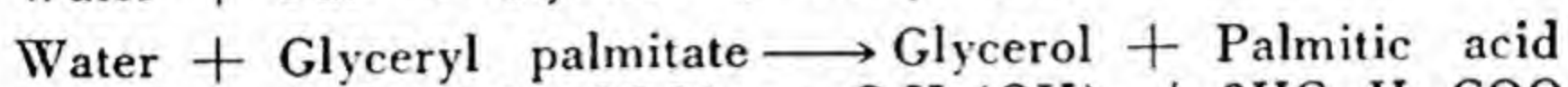
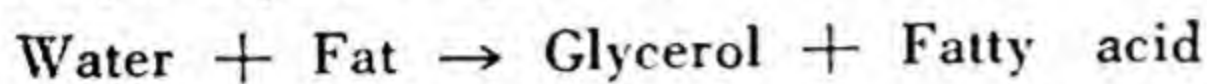


These salts are stressed because of their importance in cookery and because their hydrolysis tendencies—especially that of sodium bicarbonate—are referred to a number of times in this text in connection with the discussion of various cookery problems. The hydrolysis reactions concerned with these salts are as represented in the above equations.

Reaction of the resulting solution. In the foregoing reactions the base products, sodium and potassium hydroxides, are strong: hence most of their molecules are ionized; but the acid products, carbonic and tartaric acids, are weak: hence few of their molecules are ionized. As a consequence, in the solution in which each of these reactions occurs, the concentration of *hydroxyl ions*

from bases is *higher* than that of the hydrogen ions from the acids; hence each *solution is basic in reaction*.⁶

Hydrolysis of fats. As has been said previously, fats are composed of the glyceryl radical in combination with fatty acid radicals; therefore, the products of their hydrolysis are glycerol and the fatty acids concerned. A specific example is the hydrolysis of glyceryl palmitate:

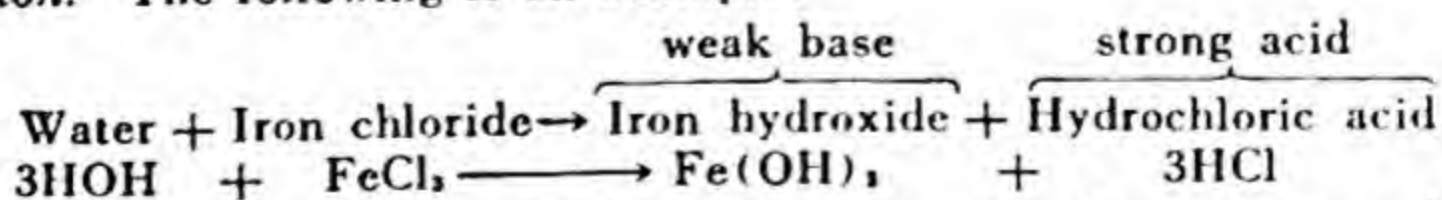


Reactions must be catalyzed. The hydrolysis of a salt begins at once upon its contact with water. But the hydrolysis of a fat must be catalyzed if it is to take place with appreciable speed at a reasonable temperature. Either an acid or a base will function in this way, but much more effective catalysts are fat-digesting enzymes such as steapsin (p. 124).

Hydrolysis of carbohydrates. Disaccharide sugars undergo hydrolysis with water under appropriate conditions to make monosaccharides (pp. 20, 24, 25). All polysaccharides are subject to hydrolysis; starches hydrolyze in steps, first to make a series of dextrans and finally glucose. Equations for reactions of these carbohydrates with water are given on page 28.

Hydrolysis of proteins. The fact that proteins react with water in hydrolysis to make amino acids is discussed briefly in the chapter on proteins.⁷

⁶ There are some salts each of which upon hydrolysis yields as products a strong acid and a weak base; hence in the resulting solution the concentration of *hydrogen ions* is *greater* than that of hydroxyl ions and the *solution is acid in reaction*. The following is an example:



⁷ Because of the complexity of the composition of carbohydrates and proteins an attempt to represent the hydrolytic nature of these reactions is beyond the scope of this text.

APPENDIX II

COLLOIDAL SOLUTIONS

Man's knowledge of colloidal chemistry is still in its infancy. A little is definitely known; much, in the fringe of the known, is subject to controversy; and a great deal is yet to be discovered. However, all scientists are agreed that colloidal phenomena are of immense importance. Ostwald, a distinguished chemist, has said, ". . . all life processes take place in a colloid system."¹ Colloidal systems must also be reckoned with in man's numerous environmental concerns. And any consideration of foods and food preparations must deal, not only with dispersions of true solution and suspension in character, but very largely with colloidal dispersions. Again to quote Ostwald, ". . . the preparation of our foods is in large measure a colloidal-chemical one,"² and yet again, "The art of cookery is a colloid-chemical art."³

Historical. A Scotsman, Thomas Graham, is usually called the "father of colloidal chemistry," both because he was the first scientist to engage consistently in serious research in this field and because he did so much by way of interesting others in this branch of chemistry.

Graham found that certain materials form gelatinous precipitates after the manner of gelatin, albumins, and glue; also that they diffuse very slowly through water and do not pass through membranes such as parchment paper. These find-

¹ Ostwald, W., and Fischer, M. H., *Theoretical and Applied Colloid Chemistry*. New York: John Wiley & Sons, Inc., 1917, p. 155.

² *Ibid.*, p. 215.

³ *Ibid.*, p. 216.

ings were quite different from those in respect to substances, including sugar and sodium chloride, which he knew to diffuse readily through water, penetrate membranes, and form crystalline precipitates from solution.

Graham named substances that give such gelatinous dispersions "colloids," derived from the Greek meaning glue, in contrast to the label "crystalloids" for such substances as sugar and sodium chloride which enter into true solution. It should be said, however, that it is now known that substances in themselves should not be classed as colloids and crystalloids, since some substances, hitherto classed as colloids, have been obtained in true solution, while crystalline substances can, under controlled conditions, be obtained in colloidal solution. As a result, in recent years the label "colloid" has come to be applied to the *character of the dispersion*, namely, a colloidal dispersion, called also a colloidal solution.

Defined. Some contrasting conditions as to true and colloidal solutions have been discussed in Chapter I, page 14. These items should be reviewed at this time. Usually a *colloidal solution* is defined from the standpoint of the size range of dispersed particles as *a dispersion in which dispersed particles have a diameter greater than one millimicron (.000001 millimeter), or greater than the diameter of those in true solutions, but less than .1 micron (.0001 millimeter), or less than the diameter of dispersed particles of suspensions (p. 2).*

Parts or phases. So it is that one should picture a colloidal dispersion as a system which includes (1) a *homogeneous liquid phase or dispersion medium*, which frequently is water alone or a water solution, and (2) a *dispersed phase which is made up of dispersed particles frequently called micelles*. An example is an albumin-in-water dispersion in which water is the dispersion medium, while discrete albumin particles, which are albumin molecule aggregates or micelles, constitute the dispersed phase (Fig. 1). A more complicated system is that of milk, which includes true solution,

colloidal solution or dispersion, and a suspension: lactose and certain salts are in true solution in the water; milk proteins are in colloidal dispersion in the foregoing true solution; fats are in suspension in this medium.

WITH WATER AS THE DISPERSION MEDIUM

While it is true that any liquid and even solids and gases can function as dispersion media, the fact remains that *water* is usually the dispersion medium, and it certainly functions in this way in practically *all* food dispersions. This accounts for the exclusive emphasis in this text on water-dispersed systems.

Gas-in-water dispersions or foams. Colloidal dispersions in which dispersed particles or micelles are made up of molecules of a gas in water as dispersion medium are of common occurrence; conspicuous among these are dispersions which are called *foams* (p. 371). In the surging of water over a precipice or against rocks, and, more conspicuously, in the beating of egg white, air bubbles can become sufficiently finely divided into smaller and smaller bubbles to be colloiddally dispersed in water.

But *foams* are extremely transient unless a *stabilizer* is present. For example: in the air-in-water system of a waterfall, dispersed air particles begin at once to coalesce and bubble out of the water. But in beaten egg white, *proteins* that are present *function as a stabilizer* since they form a protective coating (p. 371) around the colloiddally dispersed air bubbles or micelles, thereby checking their coalescence and hence their immediate removal from the colloidal system.

Liquid-in-water dispersions or emulsions. When an insoluble liquid is colloiddally⁴ dispersed in water the system is a colloidal emulsion (p. 373). Fats of egg yolk are in colloidal emulsion in the small amount of water present; liquid

⁴ When molecule aggregates of a liquid dispersed in water are colloidal in size the dispersion is a *colloidal emulsion*; when the aggregates are larger the dispersion is a *suspension emulsion*.

fats of French and mayonnaise dressings are either in colloidal or suspension emulsion, depending upon the fineness of division of the dispersed liquid fat.

The stability of emulsions depends upon various factors, including the presence of stabilizers. These factors are discussed under the more detailed study of this type of dispersion (p. 373).

Solid-in-water dispersions. There are colloidal dispersions in which micelles are molecule aggregates of solid or semisolid substances distributed in water as dispersion medium. Glue, gelatin, albumins, agar, and alkaline soaps are representative of such substances.

Size of micelles. The dispersed particles or micelles of colloidal solutions are presumably molecule aggregates of the dispersed substance in which the molecules are clustered in grape-like manner through cohesive forces. As has been said (p. 3), micelles may be composed of from hundreds to many thousands of coherent molecules.⁵ Again, this is in contrast to dispersed particles in true solutions, which are believed to be single molecules or single ions.

Why micelles remain dispersed. Since micelles are such comparatively massive particles, one would expect them to separate more or less speedily from water dispersions, owing to the pull of gravity; and gravity certainly is a separation force to be reckoned with. But with equal certainty, and despite the force due to gravity, massive micelles do remain in colloidal dispersion for longer or shorter periods. The answer, obviously, is that there must be forces, operating counter to gravity, that favor the continuance of micelle dispersion. Three of these forces are as follows:

1. **Brownian movement.** When a colloidal solution is investigated by means of the ultramicroscope (see *Note* below), it is found that the micelles are darting in a zigzag, haphazard manner—down, then up, back and forth—but

⁵ Holmes, H. N., *General Chemistry*, 4th ed. New York: The Macmillan Company, 1941, p. 425.

actually making little progress away from a mean position.

It is believed that these micellar movements are due to repeated bombardments of micelles by lighter weight but more rapidly moving water molecules of the dispersion medium. Thus it is that while the heavier micelles do start downward in response to a gravity pull, the many and frequent impacts against them, due to rapidly vibrating water molecules, have a marked tendency to cause them to rebound.

Note. The *ultramicroscope* has a lens of extraordinary magnification and the apparatus is so arranged that a powerful beam of light is directed into the dispersion from the side. If the dispersion is a true solution the observer sees a clear, transparent field, since the dispersed particles (single molecules or ions) are so ultra-tiny that light passes between them through the solution. But if there are particles present that are colloidal in size, the light beam, upon striking them, becomes reflected in all directions, and the presence of colloidal particles thereby becomes evident as points from which light is reflected. It should be emphasized, however, that the particles themselves are *not* visible but only the light reflected from them.

2. *Like charges on micelles.* Within most colloidal dispersions, all of the micelles carry *like* electric charges, either positive or negative. Therefore, within a liquid medium such as in a water-dispersed system, like-charged micelles, being free to move about, repel each other—hence their tendency to remain scattered throughout the dispersion medium.

3. *Enveloping water shells.* Dispersed colloidal aggregates of various food materials, including albumins, gelatin and gluten, adsorb water (p. 370) at their surface areas; that is, outer molecules of each micellar aggregate enter into some sort of a combination with numerous water molecules. This results in a high concentration of *combined water molecules* in these areas to form protective water shells which, enveloping the micelles, tend to prevent them (the micelles) from clustering into much larger, more massive aggregates of suspension size. The water thus concentrated at surfaces of

micelles is frequently called *bound water*, and, as long as it is held "bound," it does not exhibit the accustomed properties of water: it does not freeze; it is not subject to diffusion (p. 11); and it cannot function as a solvent for other substances. An example is the comparatively large amount of water that is used in bread-making, a considerable portion of which becomes part of the micellar structure of the gluten (p. 95), and therefore cannot act as solvent for other ingredients of the dough mixture.

Properties of colloidal dispersions in water. Some properties of colloidal dispersions have been stressed previously (p. 4); a summary tabulation also appears on page 14. Further discussion of these properties follows.

Scattering of light rays. When examined by the naked eye or under an ordinary microscope some colloidal solutions appear to be clear and transparent, as are true solutions with water as solvent; others are translucent or turbid. When examined by the ultramicroscope (p. 364) practically all colloidal solutions are from slightly to markedly turbid. The turbidity is due to the fact that micelles are large enough to catch the impinging light and reflect it at all angles. The effect that is produced is exactly like that obtained when a light beam attempts to penetrate a fog but becomes scattered from surfaces of minute water droplets of colloidal dimensions that are dispersed in air.

Boiling and freezing points same as for water. The boiling and freezing temperatures of a colloidal solution with water as dispersion medium are either the same or approximately the same as for water alone. This means, for example, that the freezing point of a gelatin-in-water dispersion is 0°C . (32°F .), while its boiling point is 100°C . (212°F .).

Not subject to osmosis. A colloidal solution exhibits little or no osmotic pressure (p. 9), hence colloiddally dispersed particles are not, as a rule, subject to osmosis; that is, they do not (usually) penetrate membranes. This is in contrast to true solutions which do exhibit osmotic pressure and

whose dispersed particles (molecules or ions) are able to diffuse through membranes.

Dialysis. As a consequence of this difference in diffusibility of their dispersed particles, whenever substances in true solution and others in colloidal solution are mingled in the same dispersion, they can be separated from each other by an appropriate use of a permeable membrane. *This separation of a substance in true solution from a substance in colloidal solution by means of a permeable membrane is called dialysis.*

Example: Should a water dispersion of both sugar, which is in true solution, and gelatin, which is in colloidal solution, be enclosed in a permeable membranous bag, and the bag with the dispersion be surrounded by just water, the sugar but not the gelatin will diffuse through the membrane into the surrounding water.

Preparation of colloidal solutions. 1. *From a true solution.* It should be recalled again that dispersed particles in a true solution of such substances as sugars (non-electrolytes) are single molecules, while dispersed particles of colloidal dispersions, or micelles, are aggregates of molecules but of such great massiveness that they can remain in dispersion under favoring conditions (p. 363). It follows, therefore, that in a true solution, whenever conditions are such that some of the dispersed single molecules are inclined to form aggregates (as would be the case in a supersaturated solution), there is a possibility that they may collect at first in small aggregates, colloidal in size. And it is indeed true that colloidal solutions are sometimes obtained in this manner: that is, by *condensation or aggregation of molecules from true solution.* But, when gathering molecule aggregates grow to dimensions greater than those within the colloidal range, the dispersion becomes a suspension and precipitation sets in.

2. *A colloidal solution from a suspension.* There is always a possibility that a colloidal solution can be made by the reverse of the foregoing process: that is, by subdivision

and re-subdivision of massive molecule aggregates of suspension size. Frequently, mechanical means such as grinding or beating are employed with the hope of eventually arriving at such a subdivision. It must be admitted, however, that it is questionable whether subdivision of more massive particles down to those of actual colloidal size is ever accomplished by these means. Even so, such procedures certainly are *aids* toward attaining substances in eventual colloidal dispersion.

Examples: A colloidal solution from true solution. When a solution of cane sugar is saturated at an elevated temperature and cooled, should crystallization not occur at once at the lower temperature, the solution will still be a true solution but supersaturated (p. 16). But, in due course, aggregation of sugar molecules will begin to take place in the dispersion; if aggregates assemble slowly the chances are that, at first, aggregates of sugar molecules will be colloidal in size, in which case a colloidal sugar solution will be formed which will persist for a time: that is, until the growing molecule aggregates become so massive as to be of suspension size when precipitation of sugar will set in. This takes place in making candies.

A colloidal solution from suspension. When salad oil and lemon juice or vinegar are beaten together the dispersed oil is at first in the form of very large molecule aggregates, certainly of suspension dimension. Beating serves to break up these large aggregates into smaller ones, and, obviously, the longer the beating is continued, the greater will be the number and the smaller will be the size of the dispersed oil aggregates. If continued long enough, some of them may be obtained in actual colloidal dispersion, but the greater number will probably be of near-colloidal, but still of suspension, size. In any event, as is well known, the longer the beating is continued the longer the persistence of the dispersion before separation of the oil from dispersion medium begins to become evident.

Peptization and peptizing agents. *Peptization* is a term that is applied: (1) to the breaking up of molecule aggregates of suspension size into aggregates of colloidal dimension through the aid of a substance called a *peptizing agent*; or (2) to the separation of larger colloidal aggregates into

smaller ones, likewise through the aid of a *peptizing agent*; or, if continued, (3) to the complete dissolution of the aggregate into the separate molecules of which it was composed, in which case the dispersion becomes a true solution. Some peptizing agents are as follows: *water*, *sugar*, a *base*—for the sake of the hydroxyl ions it yields in water solution, and an *acid*—for the hydrogen ions obtained when in water. The following are examples:

1. There are some substances, including albumins, gelatins, dextrans, agar, and soaps, whose massive molecule aggregates of suspension size become separated, more or less readily, into smaller aggregates, colloidal in character, merely by contact with water. In this case *water is the peptizing agent*.

2. The action of *sugar as a peptizing agent* is discussed in the chapter that deals with flour mixtures (pp. 76, 111).

3. Basicity, or the presence of *hydroxyl ions* provided indirectly by an excess of sodium bicarbonate (p. 82), functions as a *peptizing agent* for gluten proteins of a flour mixture. The effect is evidenced by the very tender texture of certain quick breads, presumably due to the breaking up of massive protein aggregates into smaller ones.

Precipitation of substances from colloidal dispersion. When any condition which functions as a factor in maintaining colloidal distribution of micelles is disturbed, an aggregation of micelles is favored: if the disturbance is slight or gradual, a possible flocculation due to the formation of small masses may result; if the disturbance is sudden or considerable, a precipitation in larger masses usually occurs.

By neutralization of charge on micelles. If micelles are maintained in dispersion because of repulsive forces due to their carrying like electric charges, then the presence of ions from an acid or base or salt will tend to offset the positive or negative charge on the micelles. Hence when surface areas of adjacent micelles undergo this neutralization, aggregation of micelles takes place to form larger clusters. Hydrogen ions (from acids) and hydroxyl ions (from bases) are espe-

cially potent precipitating agents for colloidal particles which carry respectively negative and positive charges.

By destruction of water shells. In some instances micelles are maintained in dispersion because of protective water shells (p. 364). Under such a condition, when these water shells are removed by dehydration, a gathering of micelles can occur, which will be accompanied by flocculation or immediate precipitation of dispersed substance. Dehydration is more commonly effected by heat, but is possible in highly concentrated solutions of some salts.

Precipitation from colloidal solutions in cookery. But substances of food interest which enter into colloidal dispersion, such as proteins of eggs and milk, are usually maintained in their dispersion *both* because their micelles carry like charges—sometimes positive, sometimes negative, and because of their enveloping water shells. Consequently, these dispersions are doubly protected against reasonable attack.

1. *Heating without added electrolyte.* Although protecting water shells in such a dispersion may be destroyed upon heating, the micelles may still remain dispersed because of their like charges.

2. *Introduction of electrolyte without heating.* If an acid or salt is introduced into the dispersion, but without heating it, micelles may still remain dispersed because of their protecting water shells.

3. *Effect of both heat and added electrolyte.* However, when an electrolyte is introduced into such a dispersion and heat is also applied, especially if the electrolyte is an acid with its contributed and potent hydrogen ions, then both dispersion forces are disturbed and micelles will begin to gather, and, when large and heavy enough, they will precipitate.

Examples: 1. It has been experimentally determined that fresh milk, with nothing added, must be heated for as long as 12 hours at 212° F. before coagulation of casein begins to be apparent. This indicates that the dehydration of casein micelles must be extensive before they begin to aggregate to an appreciable extent.

But, along with heating, if acid in sufficiently high concentration is present in the milk, coagulation takes place after a much shorter heating period (p. 146). Thus, dispersed casein of sour milk in which hydrogen ions are present—contributed by lactic acid—requires a much shorter heating period for its precipitation than when dispersed in fresh, almost neutral milk.

2. Another example of the fact that usually both heat and the presence of an electrolyte are required for precipitation of casein from colloidal dispersion is in the instance of its coagulation when salt-cured ham is cooked in milk. Obviously, heat functions as dehydrating agent for casein micelles, while the salt, being in high concentration, furnishes sufficient ions for neutralization of the micellar charges. Hence, the casein, robbed of both dispersion maintenance factors, gathers into massive aggregates and precipitates.

ADSORPTION

The phenomena of *adsorption*, *foams*, and *emulsions* have unavoidably entered into the discussions here and there in the foregoing study of colloidal dispersions. They appear in the following under specific headings for the purpose of assembling pertinent items already stressed and for further emphasis.

Adsorption. In the limited meaning as needed in connection with phenomena discussed in this text, adsorption applies to an adherence, accompanied by a resulting concentration, of molecules of a substance or of ions (p. 353) at the surfaces of molecule aggregates of solids, liquids, or gases in dispersion in water. Thus:

1. The formation of protective water shells (p. 364) by the attachment of water molecules at surface areas of micelles in colloidal dispersion in water is due to adsorption. Moreover, it will be recalled, this bound water (p. 365) no longer has the properties of water.

2. The attachment of either positive or negative ions from the dispersion medium at surfaces of micelles in colloidal dispersions may, under some conditions, be due to their adsorption at these areas. As a consequence, the micelles in any given dispersion, acquiring like charges of electricity (p.

364), are protected from coalescence and maintained in dispersion due to their mutual repulsions.

3. The films that are formed at surfaces of dispersed gas bubbles, such as protein films at surfaces of air bubbles dispersed in water (p. 372), may be due to adsorption. And as long as the clinging films persist the gas is held dispersed.

4. Likewise, in an oil-in-water dispersion the film formed at oil-and-water interfaces is due to the concentration by adsorption of protein in these boundary areas, and the life of an emulsion is prolonged as long as such a film is maintained.

Nature of adsorption. There is a difference of opinion among authorities in regard to whether adsorption is physical or chemical in nature, and it may be that in some instances actual chemical reactions are involved while in others a physical change of some sort takes place.

Adsorption versus absorption. The phenomenon of adsorption should not be confused with absorption. In absorption a gas or liquid penetrates a solid *all the way through*, owing to its porosity, such as the absorption of water by a sponge. In adsorption there is no such penetration, since, as stressed in the foregoing, adsorption involves the attachment of molecules or ions *at the surface* of dispersed aggregates.

FOAMS

In a foam, as has been said (p. 362), one is dealing with numerous air bubbles dispersed in water. The dispersion can be obtained by a vigorous agitation of water in contact with air. Also as said previously, the life of a foam is exceedingly transient unless a stabilizing agent is present; for example, the foams that form on carbonated beverages are transient because they are not stabilized in this manner.

Stabilizing agents. But there are substances which, if present in the dispersion, will insure a greater permanence of the foams obtained. Various proteins, including gelatin and proteins of eggs, are such stabilizers for air-in-water foams. For example:

1. In making certain desserts, such as a snow pudding, gelatin is used as the stabilizing agent; it becomes adsorbed at surface areas between air bubbles and water to form a film of protein which surrounds the bubbles to check their coalescence. The foam thus remains stable and, finally, becomes more or less rigid as the gelatin solidifies upon being chilled.

2. In a foam made from beaten egg white, the egg proteins become adsorbed at surface areas of dispersed air bubbles to stabilize the foam dispersion. Also, during the beating process the proteins of these films become somewhat coagulated, a condition which lends even greater permanence to the foam.

EMULSIONS

Gortner defines an emulsion as “. . . a mixture of two mutually insoluble liquids.”⁶ Briscoe, in slightly more detail, says that “An emulsion is a dispersion of very small droplets of one liquid in another with which it is immiscible.”⁷

Emulsions of foods concern always involve water and fats, with water usually as the dispersion medium for the fats. Therefore, from this more limited viewpoint *an emulsion is a dispersion in which very small droplets of fatty oils are distributed in water as dispersion medium.*⁸

It is well known that an oil-in-water emulsion, such as olive oil in water, can be obtained by vigorous shaking or beating, and that the longer the beating or shaking is continued the longer the persistence of the emulsion condition. But water has a marked tendency to squeeze out the globules of fat and these globules have a decided tendency to coalesce, so that without the presence of a stabilizing agent the life of the emulsion is brief.

⁶ Gortner, R. A., *Outlines of Biochemistry*, 2nd ed. New York: John Wiley & Sons, Inc., 1938, p. 34.

⁷ Briscoe, H. T., *General Chemistry for Colleges*, 3rd ed. Boston: Houghton Mifflin Company, 1943, p. 684.

⁸ There are dispersions in which this condition is reversed. For example, margarine is a system in which water is the dispersed substance while the fat is the dispersion medium. Vahlteich, H. W., “Custom-built fats,” *Chemical and Engineering News*, Vol. 21 (1943), pp. 1238-1242.

Emulsifying agents. Substances which stabilize emulsions are called emulsifying agents. They accomplish this by concentrating at interfacial areas between surfaces of the fat globules and the surrounding water, thus checking at the same time both the inclination of the water to squeeze out the fat globules and the tendency of fat droplets to coalesce and separate from the dispersion. Among substances which function as emulsifying agents are soaps, proteins, agar-agar, and starch.

The effect of emulsifying agents is illustrated by a mayonnaise dressing in which fat globules are held in dispersion in water through the agency of egg proteins, which, during the mixing process, become adsorbed at surface areas of the fat droplets, thus hindering their coalescence; as a result mayonnaise dressing is a fairly stable emulsion. This is in contrast to French dressing, which usually does not contain a stabilizing agent and which, therefore, maintains its emulsion condition for only a short period of time.

Agar-agar and starch are used as emulsifying agents in many commercially prepared emulsions. Among these are various mayonnaise preparations and some French dressings.

Soaps, of course, are the outstanding emulsifying agents for fats in cleansing procedures.

Most emulsions are suspensions. Since dispersed fat globules of most emulsions can be clearly distinguished when examined under an ordinary microscope, it follows that such emulsions are *suspension dispersions* (p. 2). Even so, there may be occasional emulsions in which the dispersed fat globules are small enough to be colloidal in size, in which case the dispersion would be a *colloidal emulsion*.

APPENDIX III

CARBOHYDRATE SUPPLEMENT

This section of the appendix includes some explanatory discussion of: (1) the significance of formulas in respect to the carbohydrates studied in this text, and (2) reasons for the terms dextrose, levulose, and invert sugar as applied to the carbohydrates respectively concerned.

Formulas for monosaccharides. Empirical formula. An empirical formula has reference to that which is *known* concerning measurable quantities of a compound. Thus, with

C, standing for the *atomic weight* of carbon, which is 12,
H, standing for the *atomic weight* of hydrogen, which is 1,
O, standing for the *atomic weight* of oxygen, which is 16,

these being *known* (experimentally arrived at) values for these elements as they are combined within compounds, the formula $C_6H_{12}O_6$ means that:

6×12 parts by weight of carbon 12×1 parts by weight of hydrogen 6×16 parts by weight of oxygen	}	are combined with each other in the total of 180 parts by weight (the <i>molecular weight</i>) of each of these sugars.
<div style="display: flex; justify-content: space-around; margin-bottom: 5px;"> C_6 H_{12} O_6 </div> <div style="display: flex; justify-content: space-around;"> 6×12 12×1 6×16 </div> <div style="text-align: center; margin-top: 5px;"> $\underbrace{\hspace{10em}}_{180}$ </div>		

This is in contrast to the different, but related, *theoretical* function of the same formula to represent the firmly-believed-

in atom composition of the equally believed-in molecule of each of these compounds. In this meaning:

C, stands for 1 *atom* of carbon

H, stands for 1 *atom* of hydrogen

O, stands for 1 *atom* of oxygen.

Consequently, from this theoretical viewpoint the formula $C_6H_{12}O_6$ signifies that:

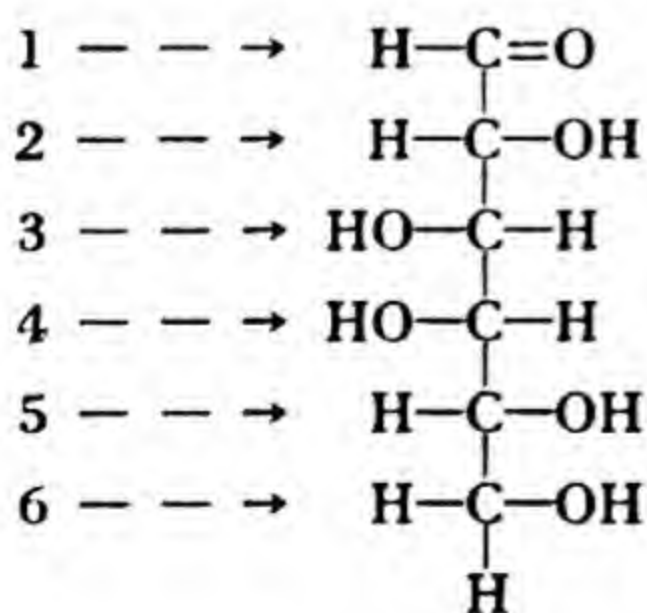
6 atoms of carbon } are believed to be combined within
12 atoms of hydrogen } each single *molecule* of each of these
6 atoms of oxygen } sugars.

Structural formula. Although glucose, fructose, and galactose do have some common properties, they also have certain different properties; hence they must be different substances. So, one may well ask, why it is that they can be different substances and still have the same composition. For the answer to this question the chemist is obliged to turn to molecules of these sugars and to the belief that within these molecules some of the atoms of carbon, hydrogen, and oxygen must be placed differently in reference to each other.

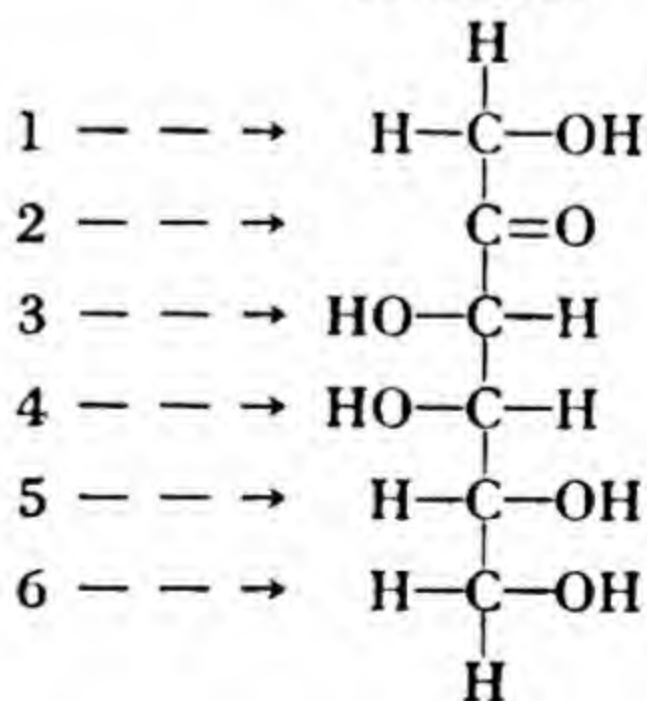
Such a representation of atom placements within a molecule as is possible on the two-dimensional surface of a page is called a structural formula. Such formulas for glucose and fructose accompany this discussion.

Structural formulas

Glucose



Fructose



It will be noted that in atom groups in positions indicated by 3, 4, 5, and 6, the carbon, hydrogen, and oxygen atoms are in identical spatial arrangement, the difference in atom placements in the two sugar molecules being in positions 1 and 2. Therefore, that which makes them different substances is believed to be the $\text{H}-\text{C}=\text{O}$ atom group in position 1 in the

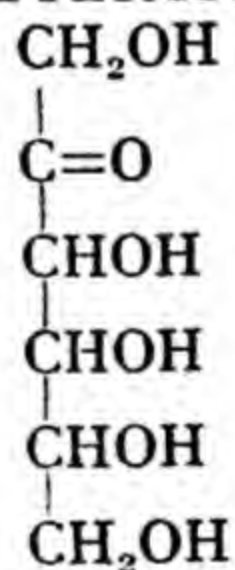
glucose molecule, which makes it behave as an *aldehyde*¹ at this point, and the $-\text{C}=\text{O}$ atom group in position 2 in the

fructose molecule, which makes this sugar a *ketone*¹ at this point. Since these are believed to be the only outstanding differences in the molecules of these monosaccharides, frequently their structural formulas appear more simply in such a way as to emphasize *only* these differentiating features, thus:

Glucose

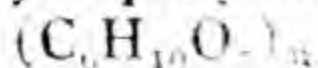


Fructose

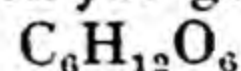


Formula for polysaccharides. On page 26 of this text it is said that polysaccharides, cellulose and starch, are composed of *identicals* in combination with each other, each of the *identicals* being glucose which is deficient in hydrogen and oxygen in the proportion to form water. The formula that indicates this composition is as follows:

Formula for polysaccharide



Formula for glucose



¹ Francis, C. A., and Morse, E. F., *Journals of Chemistry and Applications*, 2nd ed. New York: The Macmillan Company, 1943, Chapter XXIII.

Interpreted in reference to starch, this formula means that:

1. For a *measurable quantity* of starch, the molecular weight of this polysaccharide is composed of an unknown number (n) of incomplete molecular weights (radical weights) of glucose in combination with each other.

2. From a *molecule viewpoint* it (this formula) tells that each molecule of starch is composed of n incomplete molecules (radicals, as atom groups) of glucose in combination.

Reasons for the names dextrose, levulose, and invert sugar. It is impossible within the scope of this text to enter into the reasons for the use of the terms dextrose, levulose, and invert sugar with completely satisfying clarity; but it is nonetheless possible to achieve some little insight into the matter and to gain a certain amount of enlightening gratification thereby.

Polarized light. The reason why glucose is sometimes called *dextrose*, and fructose is called *levulose*, also the reason for the name *invert sugar* that is applied to a mixture of these two sugars, necessitates turning to a phenomenon in respect to light.

The light from any natural source—the sun, an electric filament, a candle—travels from the source in waves, but in waves moving, from crest to trough, in heterogeneous planes: that is, some move in a vertical, up-and-down, plane from trough to crest, some in a horizontal plane from side to side, and some in planes at various oblique angles. But there are instances in which the light, upon being reflected from a surface or in passing through certain crystals, becomes resolved into waves moving only in one plane—up and down or from side to side, and so forth. This light which travels forward with wave motions in one plane only is called *plane polarized light* or just *polarized light*.

For example: When light from any source, with waves moving in heterogeneous planes, passes through certain cry-

stals—one of which is called tourmaline—it becomes polarized. Consequently, an outstanding use of tourmaline is in instruments devised for the purpose of polarizing light; such an instrument is called a *polariscope*.

Optically active substances. This brings the discussion to glucose and fructose as representative of many compound substances whose solutions have the property of “rotating the plane of polarized light” in respect to its axis to the left or right. Such substances are called “optically active”: if their solutions rotate the plane of polarized light about its axis to the right they are “*dextrorotatory*,” if to the left they are “*laevorotatory*.”

For example: Suppose waves of polarized light to be traveling forward in a plane parallel to this sheet of paper held vertically; when a tube enclosing a solution of glucose is put in its path, for some unknown reason, the plane in which the light waves move in passing through this solution is no longer parallel to this paper, but has rotated about the common axis to the right. *Glucose is therefore dextrorotatory*; hence its name, dextrose. By the same experimental procedure, sucrose is also found to be dextrorotatory, although it bears no name which implies this fact. On the other hand, if the solution placed in the path of the beam of polarized light contains fructose, the wave plane is rotated about its axis to the left. *Fructose, therefore, is laevorotatory*; hence its name, levulose.

Why the glucose-fructose mixture is called invert sugar. As has been said, when polarized light passes through a sucrose solution its wave plane is rotated to the right, but upon passing through a solution of glucose and fructose, the products of hydrolysis of sucrose, the rotation of the wave plane is reversed or “inverted”: that is, turned to the left. Hence the mixture of glucose and fructose that is made from sucrose is occasionally called “invert sugar”; also, the enzyme, sucrase, that promotes the reaction is frequently called “invertase.” The reason why the mixture of glucose

and fructose in solution is laevorotatory is that fructose present in the mixture rotates the wave plane of polarized light further to the left than the glucose rotates this plane to the right.

APPENDIX IV

FAT-LIKE SUBSTANCES

Some substances are fat-like in character because they are closely related to fats in composition; compounds called *phospholipids* (or phospholipins) are among these. The best-known phospholipid is the substance called *lecithin*. Other fat-like substances have little or no similarity to fats as to composition, but have similar solubilities: that is, they are insoluble in water but more or less soluble in fat solvents, including alcohol and ether. The substance *cholesterol* is one of these fat-like substances.

Phospholipids. Occurrence. As is true of fats, phospholipids are present in the blood for the purpose of transportation to various cells. And all active cells of both animals and plants, also all fat-storage cells, contain both true fats and phospholipids as components. In active cells, phospholipids are greatly in excess of the true fats, and they play a very important role in vital cellular functionings. In fat-storage cells true fats are greatly in excess of phospholipids.

Composition. Elsewhere in this text phospholipids have been referred to as fat-phosphoric acid complexes; but they are more than that, since they are derivatives of fats and phosphoric acid and of nitrogen-containing compounds.

Food sources and nutritive importance of phospholipids. It has been said in the foregoing that phospholipids are essential components of all cells of living plants and animals, and they persist in these cells after death. It follows, therefore, that phospholipids are components of both vege-

tables and meats which humans use as foods—with meats providing the greater quantities, as they do, also, of fats.

And phospholipids are nutritionally of considerable importance. They comprise one of the outstanding food sources of the *element phosphorus* for the making in the body of essential phosphorus compounds. Among these are: insoluble calcium phosphate for teeth and bones; and soluble phosphate salts, which are distributed in blood, lymph, and cells, for the purpose of helping to maintain the reaction of these media slightly on the basic side of neutral—a condition concomitant with life.

Cholesterol. Cholesterol is insoluble in water but soluble in fat solvents; as said previously, it is because of these solubilities that cholesterol is classed among fat-like substances. It has no similarity to fats in composition. It is soluble in fats and in bile salts.

This lipoid doubtless plays an essential role in body processes, but what this role may be is not known with certainty at the present time. Cholesterol is present in very small amounts in active cells, and some is held in solution in fat of fat-storage cells; it is especially concentrated in brain cells and in yolks of eggs.

Food sources of chloesterol. Some of the body's needed supply of cholesterol is synthesized in the liver, but part is taken in with the food. Egg yolk is an excellent source, while milk and butter are only fair sources of this nutrient.

APPENDIX V

CLASSES OF PROTEINS

Although the commonly accepted classification of the numerous proteins into a few groups is not entirely satisfactory, it serves both to clarify some of the confusion that must of necessity accompany the study of these exceedingly complex substances and to increase one's acquaintance with them. This classification, with omissions, is given below. It will be noted that the sub-classification of *simple proteins* is largely on the basis of their dispersion and coagulation tendencies. Proteins, with very few possible exceptions, do not enter into true solution with water; some of them give colloidal dispersion, some do not; some are heat coagulable, some are not. In this tabulation, proteins which are of especial cookery significance are emphasized by means of bold-face type.

I. SIMPLE PROTEINS. The hydrolysis products of these proteins are only amino acids. Sub-classes are:

1. *Albumins*
2. *Globulins*

Only albumins are dispersible in water; both albumins and globulins are dispersible in dilute salt solutions. They are coagulated by heat.

These simple proteins are widely distributed in nature and they are always associated. **Albumins** predominate in blood and lymph; **globulins** predominate in the cells of animals, where they are maintained in dispersion in dilute salt solution. They are the simple proteins of egg white and of

milk. They are associated in plant tissues. Albumins and globulins, from different sources, vary slightly; hence the distinguishing terms serum albumin, ovalbumin, serum globulin, ovoglobulin, and so forth.

3. *Albuminoids*

These proteins are non-dispersible in water and in solutions of acids, bases, and salts.

As might be expected from their insolubilities in all of these media, these are the proteins of skeletal structures (bones, tendons, and other connective tissues) and of external protective tissues (skin, nails, hair, and so forth). **Collagen** and **elastin** belong to this class of proteins. If albuminoids are digested at all, it is very slightly. In boiling water, of all these proteins, collagen, alone, is changed to **gelatin**, which is water dispersible.

4. *Glutelins*

5. *Prolamines*

Both glutelins and prolamines are non-dispersible in water and salt solution. Glutelins give dispersions in dilute solutions of acids and bases. Prolamines are dispersible in alcohol solution.

Glutenin, one of the proteins of wheat, is the most important of the glutelins. **Gliadin**, another protein of wheat, is the most important of the prolamines. Their chief importance lies in the fact that when they, together, are treated with water, **gluten** is formed which is capable of establishing a mesh-like structure as in flour mixtures.

II. COMPOUND OR CONJUGATED PROTEINS. These are composed of simple proteins in combination with non-protein substances; hence, upon hydrolysis the products are amino acids and the non-protein substances concerned. Sub-classes are as follows:

1. *Phosphoproteins* are proteins which upon hydrolysis yield amino acids and a phosphoric acid complex.

These proteins are essential components of protoplasm. As foods they constitute important sources of the element phosphorus (p. 381). **Casein** (p. 145) of milk, and **ovovitellin** of egg yolk (p. 177) are two phosphoproteins.

2. *Hemoglobins* upon hydrolysis yield **heme** or **hematin** (p. 199) and amino acids as products. Blood hemoglobin is an example.

3. *Nucleoproteins* upon hydrolysis yield amino acids and nucleic acid.

These are components of cell nuclei. The thymus, pancreas, and liver, being largely made up of nucleated cells, are especially rich in nucleoproteins.

III. DERIVED PROTEINS. These proteins are products either of some slight alteration or partial hydrolysis of proteins. The following are examples:

1. *Products of slight protein alteration:*

Paracasein, made from casein of milk through action of rennin (p. 147).

Heat coagulated proteins.

2. *Products of partial protein hydrolysis:*

Proteoses	}	See page 139.
Peptones		
Peptids		

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